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MILITARY OPERATIONS RESEARCH SOCIETY

Analyzing C4ISR for 2010
Mini-Symposium and Workshop

27-29 October 1998
Center for Strategic Leadership, Army War College
Carlisle Barracks, PA

Chair
RADM Robert Nutwell, USN
Technical Chair
Dr. Russ Richards

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1. INTRODUCTION

The rapid advance of information systems technology and the broader spectrum of threats we face has caused our Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) procedures and architectures to undergo profound changes. Joint Vision 2010 highlights "Information Superiority" as the major enabler for achieving Full Spectrum Dominance and C4ISR is the major contributor to achieving information superiority. This notwithstanding, the resource constrained environment of the Department of Defense (DoD) is forcing decision makers to face tough choices in determining the allocation of investment between C4ISR and the other contributors to force effectiveness. Cogent analyses are needed to support these decisions.

Heretofore, the analysis community has not effectively been able to assess the relative contribution of C4ISR to force effectiveness vis-a-vis other factors. Past analyses have not been adequate for the new emphasis on C4ISR. The analytic community must now posture itself to address the analysis of C4ISR for 2010 and beyond.

The Military Operations Research Society (MORS) organized and conducted a workshop to examine the question of *Analyzing C4ISR for 2010.* That workshop was held 27-29 October 1998 at the Center for Strategic Leadership, US Army War College, Carlisle Barracks, PA. The General Chair of the Workshop was RADM Robert Nutwell, USN. Captain Jay Kistler, USN, was the Deputy Chair and Dr. Russell Richards, MITRE Corporation, was the Technical Chair.

1.1 Goals and Objectives of the Workshop. The goals of the workshop were to:

1. Share information on the current state of C4ISR analysis.
2. Determine the appropriate metrics and methodologies for analysis of C4ISR for 2010.
3. Define key areas of improvement for the application of analysis in support of decision making on C4ISR investments and warfighting utility.

The objectives were to:

- Enumerate the relevant issues pertaining to the analysis of C4ISR in 2010.
- Identify metrics that are sensitive to the effects of C4ISR on force-level effectiveness.
- Assess methodologies to analyze and quantify the effectiveness of C4ISR
- Evaluate appropriate tools to measure the benefit of C4ISR.
- Discuss the requirements for and employment of advanced tools, methods, and research.

1.2 Approach. The subject of C4ISR analysis was examined in the context of a number of different mission areas. A working group was assigned to each mission area. The mission areas were:

1. Major Theater War.
2. Smaller Scale Contingencies.
3. Operations Other Than War.
4. Infrastructure Assurance.
5. Peacetime Engagement.

In addition, separate working groups were assigned to the focus areas of Information Architectures and Analytical Techniques and Tools.

1.3 Taskings. Consistent with the goals and objectives of the workshop, each working group was charged to undertake five taskings:

1. Characterize C4ISR within the working group mission area or focus area.
2. Define the relative worth of C4ISR.
3. Develop and recommend Measures of Merit (MoM).
4. Identify and describe tools.
5. Analyze, synthesize and infer.

2. BACKGROUND

The increasing emphasis on joint operations driven by the Nichols/Goldwater legislation, the information age and the changing military threat have led to significant changes in the Department of Defense. The Joint Warfighting Capability Assessments (JWCAs) are performed for each of 11 joint warfighting capability areas. Reflecting the emphasis on conducting joint operations, all of the warfighting capability areas cut across service boundaries. With most of the analysis tools having been developed by a single service to support the specific needs of that service, the tools available to support joint analysis and to support tradeoff decisions which cross service boundaries are deficient. This is particularly true for evaluating the contributions of C4ISR.

Recognizing these deficiencies, the Vice Chairman of the Joint Chiefs of Staff and Chairman of the Joint Requirements Oversight Council (JROC) in 1995, Admiral William Owens, asked the Military Operations Research Society to host a workshop to look at the ability of the community to support the JWCAs. That workshop was conducted October 1995. It had working groups for each of the eleven joint warfighting capability areas. Each working group evaluated the "health" of the analysis capabilities as they pertain to the capability area. Most reported serious deficiencies in the models, simulations, databases, measures and methodologies. This was particularly true for the C2IW and ISR working groups. Influenced significantly by that discouraging evaluation of the tools, Admiral Owens and other senior decision makers in the Department of Defense took steps to remedy the situation.

Two manifestations of the actions taken to remedy the problem were the initiation of the Joint Analytic Model Improvement Program (JAMIP) and the C4ISR Decision Support Task Force (DSTF). The JWARS simulation development effort and the Joint Data System (JDS) program for improving the databases for supporting joint analysis were two programs that evolved from JAMIP. The DSTF concluded that the existing tools were severely deficient for meeting the C4ISR analysis requirements. It also concluded that DoD needed an organization focusing specifically on C4ISR analysis. That task force led to the creation of the C4ISR Decision Support Center (DSC) and the C4ISR Joint Battle Center (JBC).

In the few years following the DSTF, there has been continuing interest and emphasis on C4ISR analysis. There has been much work towards improving the capabilities of the tools (e.g., JWARS, C4ISR Federation, NETWARS), and there have been several major C4ISR analysis efforts including the C4ISR Mission Assessment (CMA) conducted to support the Quadrennial Defense Review (QDR). Nevertheless, there are still many problems with assessing the contribution of C4ISR to warfighter effectiveness and to trade-off the contributions of C4ISR with other systems. This MORS workshop provided an opportunity to reassess the situation and to offer recommendations to our DoD Sponsors about improving the health of C4ISR analysis.

3. THE WORKSHOP ACTIVITIES

3.1 Plenary Sessions. The workshop kicked off the first day with four excellent presentations, each of which validated the need for our meeting and which offered challenges to the participants.

"The Decision Maker's Perspective." Mr. Art Money, the Assistant Secretary of Defense for Command, Control, Communications and Intelligence (ASD(C3I)) and the Department of Defense's Chief Information Officer, started things off with a keynote address providing the decision maker's perspective. He emphasized the importance of information superiority and acknowledged that the topics and goals of our workshop were timely and on track. His talk provided an interesting historical perspective on conflicts involving the United States. Mr. Money considered the six US security epochs listed in Table 1.

Table 1. Epochs in US Security History

Epoch	*Time Period*	*Description*
1	To 1820	Revolutionary War
2	1820-1900	Civil War
3	1900-1920	WWI: Birth of Communism
4	1920-1945	WWII: Fascism defeated, atomic bomb, massive technology advances (aircraft, communications, radars, UHF, etc.)
5	1945-1993	Cold War: monolithic threat (Soviet Union), Vietnam, Korea, ICBM, Fulda Gap, SAC; predictability
6	1993-1998	Coalition War: collapse of a major power, walls come down, transnational threat, non-government powers, no geographic boundaries, asymmetric warfare, critical infrastructure protection, information warfare, sensitivities of information, operations other than war

The first epoch covered the establishment of the US as a nation that was pursuing an isolationist foreign policy. This isolationism continued through the second epoch, from 1820-1900, when the US was involved with the Civil War and later becoming a world power. The third epoch, from 1900-1920, was characterized by World War I, the collapse of Europe and the birth of communism. The fourth epoch, from 1920-1945, witnessed massive technological advancement, and included World War II, the defeat of Fascism and the development of the atomic bomb. Epoch number five, from 1945-1990, includes the Korean War, the Vietnamese War, the Cold War, the eerie predictability of a monolithic threat and bi-polar powers.

The sixth security epoch, from 1990 to the current time, presents a new paradigm. The collapse of the Soviet Union as a world power, a major desert war and the emergence of many turbulent forces have highlighted it. These include the 500-700 year old grudges between often well armed nation states, technological advancement and commercial expansion, the proliferation of WMDs, and threats to the US that include quasi-governmental organizations (Bin Laden), transnational entities and tribes. The threats are more asymmetric than prior threats and include threats to the US infrastructure and cyber attacks.

This perspective demonstrated the shift in the defense requirements that has taken place during our country's history and demonstrated why there is increasing interest in C4ISR.

Mr. Money emphasized the importance of information superiority — providing the right information to the right people in the right format at the right time. However, he also emphasized the need to assess the Return On Investment (ROI) for C4ISR systems — precisely the reason for the MORS workshop. He challenged the workshop to determine *what a pound of C4ISR is worth*. He stated that we do not presently do this well, and we need better tools and methodologies to evaluate the contribution that C4ISR makes to force effectiveness. He specifically highlighted the need for better models and simulations and for better measures.

3.1.2 "The Operator's Perspective." Mr. Money's talk was followed by two presentations providing the operator's perspective. The first was given by Brig Gen Carol Elliott, the Vice Director for the Joint Staff J-2 and the Team Lead for the Intelligence, Surveillance and Reconnaissance (ISR) Joint Warfighting Capability Assessment (JWCA). She was a voice of experience, for she has been grappling with the problem of determining the ROI for ISR during the last couple of years, most recently the Recce 2010 Study. She echoed the remarks of Mr. Money in indicating that the analysis community faces big challenges in determining the ROI for ISR, and in acknowledging that we do not do this very well.

She stated that the JWCA process has a voracious appetite for people who can bring coherent analysis to the table. She stated that analysis of the value of C4ISR would require innovative, new approaches.

General Elliott gave a pithy discussion of analysis pitfalls derived from her own experiences in supporting the ISR JWCA. Some of the points that she made were:

- Make sure that terms such as "Dominant Battlespace Awareness" are well defined.
- Make sure that all analysis assumptions are made clear to the decision makers.
- The use of notional data is a real problem.
- Be sure the analysis does not exclude people as part of the ISR process.
- Be sure that the measures of merit are relevant (it is not just a problem of mathematics).
- It is always difficult to determine how much analysis is enough.
- Whatever the results, you will be misquoted, misinterpreted, attacked, disregarded or all of the above.
- Keep the "I" in ISR. It is more than a question of platforms.
- Models are not adequate for the types of tradeoff analyses that they are being asked to do. Models used for ISR analyses were developed for other things. Better measures are needed to assess the contribution of ISR.

General Elliott closed with five recommendations for C4ISR analysis:

1. Define effectiveness.
2. Replace assertions with facts.
3. Scrutinize results for what's missing.
4. Explain your results to your administrative staff to see if your explanation passes the common sense test.
5. Remember that it's people, stupid!

Colonel William Cooper, representing the Joint Staff J-6, provided the second operator's perspective. Like General Elliott, Colonel Cooper is a JWCA team leader – for the Command and Control area. Colonel Cooper's presentation focused on the problems with the legacy stovepiped tools for addressing C2 issues. He discussed the need for service models to interoperate so that joint issues can be addressed. Colonel Cooper also stressed the need for more than M&S to support C4ISR analyses. He discussed the need to coordinate joint experimentation activities of USACOM J-9 with the modeling and simulation. He saw the opportunity to validate models with experiments. He closed by challenging the community to develop better models for C4ISR and to tie weapons systems and C4ISR together.

3.1.3 Technical Perspective — "C2 Assessment: Past, Present and Future." Dr. Stuart Starr, MITRE Corporation, completed the day's invited presentations with a historical perspective on the changes that he has seen over the past 25 years with respect to command and control assessments. Dr. Starr discussed three "ages":

- *Awakening*
- *Dark Ages*
- *Renaissance*

Prior to 1975, there was general insensitivity to C2 issues. C2 was often ignored or assumed to be perfect or, if considered, it was often treated simply as a patch (e.g., an additional term in Lanchester's equations). The little bit of analysis of C2 that was done was fragmented within the Department of Defense. The decade from 1975–1985, the *Awakening*, saw an increased interest by the senior leadership in C3I leadership as there was an increased awareness of the importance of C3I and a need to justify expenditures on C3I. This increased interest was manifest through several key initiatives which included symposia and workshops (at least one sponsored by MORS on C3I Measures of Effectiveness), the creation of new organizations (e.g., the C2 Research Program and the Naval Postgraduate School C3 Curriculum), major multi-year studies focusing on C3I and increasing resources devoted to C3I assessment. New assessment methodologies and processes such as the Modular C2 Evaluation Structure (MCES), Headquarters Effectiveness Assessment Tool (HEAT), Mission Oriented

Approach (MOA) and new tools such as synthetic environments like the Identify Friend or Foe Network (IFFN) Testbed greatly improved the ability to assess the effectiveness of C3I. Much of the credit for the *Awakening* was due to the strong leadership of people like Robert Hermann and Harry Van Trees.

The *Awakening* period was followed by a six year period from 1985–1990, the *Dark Ages*, in which DoD leadership showed a significant reduction in interest in C3I assessments. This was due to relatively high budgets for C3I and an emphasis on C3I system acquisition. Because resources were plentiful, there was little concern about return on investment for C3I. The influence of analysis organizations waned significantly during the *Dark Ages*.

The *Dark Ages* were followed by the *Renaissance* period (1991–Present). This was brought about by a combination of factors which included profound geopolitical changes (e.g., the dissolution of the USSR and the Warsaw Pact), severe resource reductions and changing paradigms such as the Revolution in Military Affairs (RMA) and Simulation Based Acquisition (SBA). Some of the manifestations of the renewed interest in analysis and C3I assessments were the creation of the Defense Modeling and Simulation Office, the revitalization of the CCRP, the C4ISR Decision Support Task Force, the creation of the C4ISR Decision Support Center (DSC) and the Joint C4ISR Battle Center (JBC), the C4ISR Mission Assessment (CMA), the initiation of the Joint Analytic Model Improvement Program (JAMIP), the development of major analysis simulation models which made major improvements in the representation of C4ISR (e.g., JWARS, EAGLE, ARES, C4ISR Model and NSS) and the establishment of the Joint Experimentation Directorate within the US Atlantic Command (USACOM). MORS has played a major role in the *Renaissance* in C4ISR assessment. The following MORS-sponsored workshops have contributed to the renaissance:

- C3IEW MOEs
- VV&A for M&S
- JROC Analysis
- Advanced Distributed Simulation for Analysis
- OOTW Analysis Methods and Techniques
- Quick Response Analysis Methodologies (QRAM)
- Warfare Analysis and Complexity ("New Sciences")
- QDR Lessons Learned
- SIMTECH 2007

Two NATO Panels made significant contributions to the renaissance during this period. The NATO Panel 7 Working Group conducted several meetings aimed at assessing the impact of C3I on the battlefield. The NATO Studies, Analysis and Simulations (SAS) Panel published a Code of Best Practices (COBP) for Assessing C2 in 1998. The COBP recommended an Assessment Methodology, which consisted of the following elements:

- Problem Structuring
- Human Factors and Organizational Issues
- Scenarios
- Measures of Merit
- Tools and Their Applications
- Data
- Risk and Uncertainty
- Reporting

Dr. Starr then referenced General Larry Welch in making the case that DoD leadership must initiate and sustain some major cultural changes to track the other changes that have occurred if our C4ISR analyses are to be relevant. Table 2 describes the areas in which cultural changes are needed and the nature of the changes.

Table 2. Needed Cultural Changes

Area	*Sub-Area*	*From*	*To*
Institutional	Outcomes	Protected/Advocacy	Open/Unbiased
	Review/VV&A	Bureaucratic	Subject matter expert
	Organizational	Stovepiped	Collaborative
M&S	Orientation	Model	Subject matter
	Processes	Opaque	Transparent
	Data	Limited to "validated"	Include possibilities
	Algorithms	Stable, traceable	Allow for non-linear
	Mission Orientation	Cold War	New World Disorder
Processes	Uncertainty	Suppress	Illuminate
	Scenarios	Few, "blessed"	Full range
	Analysis	Force-on-force	Military-social-economic
	Forces, concepts	Symmetrical	Asymmetrical
	Trade-offs	Limited	Full range
	Scope	Narrow (force structure; military worth of equipment)	Broad (Forces; equipment; doctrine; concepts; C2; ...)

Dr. Starr closed his presentation with a discussion of selected recommendations from the COBP, a characterization of the C2 assessment base and some major challenges. Since many of his recommendations and challenges reappeared in some of the briefouts, we will fold in his recommendations and challenges with those of the working groups later in this report.

3.1.4 "Federated Analysis of C4ISR in Warfare." On the second day, Mr. Charles Taylor, C4ISR Decision Support Center, gave an interesting luncheon presentation sharing some of his recent experiences in grappling with C4ISR analysis problems at the DSC. Mr. Taylor made a strong point that no single model will be adequate to meet the needs of the C4ISR analysis community. He advocated the use of a federation of M&S tools to support the analysis.

3.1.5 "Blackhawk Down." Mr. Mark Bowden, a reporter for the Philadelphia Enquirer, gave a luncheon presentation on the third day. His multi-media presentation described the gripping real-life activities surrounding the attempt to rescue the US crew of a helicopter that crashed in Mogadishu. His presentation highlighted some of the critical problems with our C4ISR systems.

3.2 Conduct of the Working Groups. After the first day's plenary session, the participants broke into their respective working groups. In addition to addressing the taskings of the Workshop, each working group was instructed to evaluate the health (in the mission area) of the state of C4ISR analysis.

3.3 Synthesis Team. As has become customary for MORS workshops, a Synthesis Team was created to provide a holistic view of the deliberations of all of the working groups participating in the workshop. Consistent with that goal, the team included representatives from OSD, each of the services, industry, FFRDCs and academia. Selected members of the Synthesis Team actively participated in each of the working groups to help the groups keep on track with respect to meeting the objectives of the workshop and to report on progress or difficulties encountered by the groups. The Synthesis Team convened periodically during the course of the workshop to discuss and compare the evolving findings and recommendations of each working group.

3.3.1 Products of the Synthesis Team. The Synthesis Team drew on its periodic deliberations and its observations of the activities in the working groups to develop some broad observations about the nature of the problem and to formulate a set of cross-cutting findings and recommendations. The products of the Synthesis Team are summarized below.

3.3.2 Broad Observations. As a consequence of monitoring the deliberations of the individual mission-oriented working groups it was clear that there was broad variability in the maturity of the individual mission areas (e.g., level of domain knowledge; available tools and data; experience in analyzing the C4ISR systems and processes associated with those missions). Based on the perceptions of the Synthesis Team, it was concluded that one would rank the missions on a qualitative "maturity scale" as follows (most mature to least mature):

1. Major Theater War (MTW)
2. Smaller Scale Contingency (SSC)
3. Operations Other Than War (OOTW)
4. Peacetime Engagement (PE)
5. Infrastructure Assurance (IA)

This maturity ranking should not be surprising as it tracks with the total amount of effort devoted to C4ISR analysis for the different mission areas.

The Synthesis Team further observed that many of these mission areas subsume qualitatively different sub-missions. For example, Operations Other Than War (OOTW) subsumes Humanitarian Assistance (HA), disaster relief, peace keeping and peace enforcement. These sub-missions are so different in their nature and maturity that it can be misleading to making overarching statements about the overall mission area. For example, some of the sub-missions in OOTW would be rated very immature.

The Synthesis Team also noted problems with definition for several of the mission areas. Notably, the distinction between SSC and OOTW was not initially clear. To eliminate confusion, the chairs of these two working groups "defined" their areas of focus to make the distinction. Furthermore, the Peacetime Engagement Working Group spent a significant amount of time crafting a definition of PE. Finally, because infrastructure assurance was a relatively new mission area, it was necessary for the co-chairs to clearly define IA.

3.3.3 Major Issues. As the Synthesis Team monitored the deliberations of the individual working groups, it identified several major issues that were raised by those working groups. The major issues are summarized in Table 3. Note that, although there are considerable differences in those issues, several crosscutting issues are apparent. These crosscutting issues involve difficulties associated with data and Measures of Merit (MoMs). These specific crosscutting issues are discussed in the findings and recommendations that follow.

Table 3: Major Issues

Mission Area	*Major Issues*
MTW	Few accepted data sources; Modeling Red C4ISR; Existing data does not map to DPG scenarios
SSC	MoMs need sufficient pre-definition
OOTW	Data; Softness of MoMs (e.g., public opinion); OOTWs are not all the same
Peacetime Engagement	Definition of Peacetime Engagement
Infrastructure Assurance	Data (much of it is Blue data); Higher-level MoMs; Scope of problem/ability to decompose meaningfully Dealing with the interactive nature of the problem
Information Architectures	How does one score an architecture and communicate the results appropriately?
Analytical Tools and Techniques	Cognitive modeling; Broad array of missions; Size of the trade space; Representation of Red data

Each working group assessed the current state of the health of C4ISR analysis in its mission area. The template that was developed for the forthcoming NATO COBP for Assessing Command and Control (and which was introduced by Dr. Stuart Starr in his plenary presentation) was used for the working group assessments. Table 4 provides an 'aggregate' stop light assessment (Green = good; Yellow = fair; Orange = significantly deficient; Red = poor), aggregated qualitatively across the results of the individual working group assessments.

Table 4. Aggregate Assessment of the Health of C4ISR Analysis

Element	*Aggregate Assessment*
Problem Structuring	Orange
Human Factors/ Organization	Orange
Scenarios	Yellow
Measures	Orange
Data	Red
Tools	Red
Risk and Uncertainty	Orange
Report	Orange

Note that none of the elements were rated Green. Also, two of the critical steps (Data and Tools) were assessed as being Red, and five of the steps (Problem Structuring, Human Factors/Organization, Measures of Merit, Treatment of Risk and Uncertainty and Report Documentation and Availability) were assessed as being Orange. Only the Scenario Generation step was rated as good as Yellow.

These observations suggest concern about the ability of the analysis community to adhere to the processes in a strawman COBP. These results led the Synthesis Team to highlight findings and recommendations in five areas: COBP, three key elements of the candidate COBP and the overall relationship between the producer and consumer of C2 analyses.

3.3.4 Findings. The findings of the Synthesis Group are discussed below.

COBP. The NATO COBP provides an interesting and useful first step towards developing a sound foundation for C4ISR analysis. However, the scope of the COBP was restricted to C4ISR analysis in the context of conventional warfare. As this workshop revealed, the problem of analyzing C4ISR for 2010 will involve a host of additional mission areas, which pose unique problems for the C4ISR assessment community. Thus, an expanded, community-endorsed COBP is needed to support the C4ISR assessment problem, in all its dimensions.

Measures of Merit (MoMs). Over the last thirteen years, MORS has conducted several workshops on the issue of developing measures of merit for command and control assessments [Ref. 1, 2]. Those workshops proposed the concept of a hierarchy of MoMs that would range from measures of system performance through measures of mission effectiveness. The various mission-oriented working groups at this workshop appeared to support this conceptual approach to the problem. However, it was concluded that the hierarchy must be extended to deal with the needs of new world disorder missions. The Architecture Working Group also observed that it lacked MoMs to support the effective assessment and comparison of architectural options. In particular, it called for MoMs that would relate system architectural characteristics to operational outcomes.

Data. A decade ago, at a MORS Workshop on Simulation Technology 1997 (SIMTECH 97), Dr. Walt LaBerge observed that "without data we are nothing" [Ref. 3]. That thought clearly prevailed in this workshop. Each working group highlighted data deficiencies. The specific concerns varied by Working Group and included the following challenges:

1. Acquiring the Blue system data needed to perform vulnerability assessments of critical infrastructures.
2. Acquiring the data appropriate to some currently ill-defined future military operation.
3. Characterizing Red's C4ISR systems and critical infrastructures.
4. Gaining access to needed data in a timely fashion.

5. Collecting and making better use of data emerging from Service and Joint Advanced Warfighting Experiments.
6. Validation and certification of data.

Tools. Many of the speakers at the workshop focused their remarks on modeling and simulation and its important role in C4ISR analysis. It is clear, however, that no single class of tool (and certainly no single tool within a class) can satisfy C4ISR assessment needs adequately. There is a broad spectrum of tools that a C4ISR analyst can choose from, that vary with respect to the time to create and apply the tools, the cost to create and apply them, the amount of abstraction and their credibility (see Ref [4]).

Relations between Providers and Consumers of C4ISR Assessments. Many Working Groups observed that the relationships between the providers and the consumers of C4ISR assessments are strained. By relying on complex, opaque M&S tools, many providers are failing to make their analyses transparent and understandable (e.g., "Why did I come to that conclusion? My model told me!"). Similarly, consumers are frequently not "educated customers." For example, they fail to articulate issues in a way that is amenable to responsible C4ISR analysis. Or, they fail to give the provider adequate resources to either create the needed tools or to perform the assessment.

3.3.5 Recommendations. This section provides recommendations, that the Synthesis Group felt would improve the state of C4ISR analysis. Each of the listed findings (Section 3.3.4) are addressed.

COBP. Although the preliminary review of the NATO COBP was promising, we recommend that a more thorough, in-depth assessment of the product should be undertaken to see if it meets (at least some of) the needs of the US C4ISR analysis community. MORS is in the best position of any US organization to organize and execute such an assessment.

If such an assessment is undertaken and it endorses the NATO COBP as a preliminary product, the following steps should be pursued. First, the product should be disseminated broadly to the C4ISR assessment community, along with any caveats that emerged through the assessment process. MORS has an efficient distribution network for making such information broadly available. Second, consideration should be given to employing the product in defense universities, such as the Naval Postgraduate School (NPS) and the Air Force Institute of Technology (AFIT), to educate young analysts.

In view of the limited scope of the NATO COBP, efforts should be supported to extend the product to address new world disorder issues. NATO is forming Studies, Analysis and Simulation (SAS) Panel-015, to explore the feasibility of extending the initial COBP to deal with issues associated with OOTW and information operations. Those efforts should be supported by MORS (e.g., by providing representatives to the deliberations; appropriate briefings and case studies to the participants; a peer review of the panel's product) to ensure that the resulting efforts are of greatest utility to the US C4ISR assessment community.

Measures of Merit. To respond to the needs of new world disorder missions, efforts are needed to formulate the upper levels of the MoM hierarchy. For example, in the mission areas of smaller scale contingencies and operations other than war, measures are needed to characterize political-institutional-social stability. For example, are the bodies of government functioning effectively? Are educational institutions operative? Are children playing on the soccer fields? Similarly, in the area of infrastructure assurance, MoMs are needed to reflect public confidence in key infrastructures (e.g., confidence in the finance and banking sector as measured by the value of the Dow Jones Industrial Average and the value of the dollar versus the Euro). These needs suggest that MORS should convene a workshop on expanded C4ISR MoMs for new world disorder missions.

To satisfy the needs of the architectural community, steps should be taken to explore

options to develop MoMs that can be used to assess and compare architectural options. One possible course of action would call for OSD to convene an Integrated Process Team (IPT) of stakeholder organizations to address this issue. MORS could provide the facilitators to conduct such an event.

Data. The depth and breadth of the data concerns are such that a new institutional mechanism is needed to deal with the totality of the problem. This mechanism should deal with the full life cycle of the data problem, to include data standardization; data acquisition; verifications, validation and certification; transformation (into a form that is useful to the C4ISR assessment community); and data storage and access. Currently, there are a number of organizations that are involved with significant facets of the problem. These include OSD's C4ISR Decision Support Center (DSC), PA&E's Joint Data System (JDS), Defense Modeling and Simulation Office (DMSO) Modeling and Simulation Operational Support Activities (MSOSA), and J6's Joint Defense Information Infrastructure Control System (JDIICS) and NETWARS activities. OASD(C3I) should take the lead in forging these fragmented efforts into a complete, mutually reinforcing solution to the total problem.

Tools and their Application. It is important that C4ISR analysts be aware that a broad mix of tools exists beyond the usual simulation tools, and it is important that the analysts be conversant about their strengths and weaknesses. In particular, where appropriate, C4ISR assessments should take better advantage of analyses based on basic operations research and physical principles; structured frameworks for analysis; expert elicitation tools (e.g., groupware); wargames; analytical systems dynamics models; applications of the "new sciences" to deal with complex adaptive systems; and multifunctional tools (e.g., tools that can support analyses and mission rehearsal). In all instances, assessors should assiduously pursue efforts to perform responsible levels of Verification, Validation and Accreditation (VV&A) for the tools selected. MORS should lead the way in determining what is a "responsible level of VV&A." [Note: the SIMVAL 99 workshop that MORS is hosting in 1999 should shed light on this issue.]

Because each type of tool has strengths and weaknesses, it is important to select and orchestrate a complementary set of tools. In the past, this concept has been limited to the model-test-model paradigm. However, it would be appropriate to generalize that concept to incorporate a broader set of tool types. For example, it might be desirable to consider an "expert elicitation-real world experience-test-model" paradigm, that expands the set of tools that are orchestrated.

Provider-Consumer Relations. The MORS Mini-Symposium on "Quick Reaction Analysis Requirements and Methodologies (QRAM)" [Ref. 4] recognized and addressed the issue of provider-consumer relations. That workshop recognized that there should be a "contract" between providers and consumers, recognizing the mutual responsibilities of both sides. It is recommended that the draft "contract" be updated and refined to reflect the lessons learned from this workshop. As a further step, a COBP should be developed (perhaps in the form of a check list) to help educate consumers about the attributes of sound C4ISR analysis. This "check list" could be patterned after the COBP that the AIAA Information and C2 System Technical Committee is developing for OSD on C2 experimentation.

3.3.6 Synthesis Group Summary. The situation with respect to the current state of C4ISR analysis runs the gamut from bad news to good news. The bad news is that the C4ISR assessment problem is getting substantially more difficult. We are confronted with a host of new world disorder missions and issues for which we lack the key elements of effective C4ISR analyses (particularly relevant data and tools). In addition, these issues are in a current state of flux, making it difficult to get traction on the problem. One of the most dramatic examples of this challenge is the infrastructure assurance problem, where the infrastructures and the threats to them are changing dramatically. More bad news is that currently, we generally do not

do a satisfying job in performing C4ISR analyses. Although there are counter-examples to this statement, it is recognized that most studies of conventional conflict fail to live up to the NATO COBP.

The good news is that we are beginning to understand a great deal more about the C4ISR assessment problem. We are starting to recognize the importance of C4ISR in the context of the many missions that DoD must perform. We are also starting to recognize what we don't yet understand and the practices that should be followed to perform credible C4ISR analyses. Finally, this workshop itself provides some more good news. If the recommendations of the workshop are implemented successfully, it will provide the foundation for the C4ISR community to work collaboratively to attack the most critical of our shortfalls.

4. INDIVIDUAL WORKING GROUP SUMMARIES

The above sections discussed the observations, findings and recommendations of the Synthesis Group aggregated over all of the working groups. The sections below provide similar products for each of the working groups. Each section concludes with the assessment of the working group as to the health of C4ISR analysis in the mission or specialty area. The discussions below represent only a summary of the key points from the deliberations of the working groups. More details are provided in the complete annotated working group briefings that are found in the appendices.

4.1 Major Theater War (MTW) Working Group. The MTW working group was co-chaired by Mr. Charles Taylor, C4ISR Decision Support Center and Dr. Mark Youngren, MITRE Corporation. Although the MTW area is certainly the most mature of the mission areas with respect to analysis attention, the working group still found serious deficiencies in its assessments.

4.1.1 Analysis Setup and Problem Definition. The group felt that the most meaningful part of the analytical process is the clear articulation of the questions and working with the decision maker to ensure the question is properly understood by all and framed so that an answer can be derived. It is essential to clearly define the objectives and constraints and to have good scenarios and data.

4.1.2 Models and Simulations. Models and simulations are the workhorse tools for C4ISR analysis in the MTW area, but the legacy M&S tools are, for the most part, models that were not built to analyze Joint problems and they do not model most aspects of C4ISR very well. For example, it is usually the case that doctrine is hard wired; C2 is scripted; there is limited explicit representation of C4ISR systems; limited ability to map the contributions of C4ISR systems to combat outcomes; fusion is represented poorly (if at all); human factors are not represented at all; Red C2 is not reactive to Blue actions; COMINT and HUMINT are not modeled well; and the flow of *information* is poorly represented.

Other serious deficiencies in our existing M&S tools are the modeling of non-combat, Red C4ISR, decision heuristics for Red rules of engagement, information operations, the play of coalitions and the representation of the effect of maneuver on Red behavior.

Current state of the art. The working group raised concerns about the ability of the various simulations under development (e.g., JWARS) to significantly improve on the above deficiencies. They believe that much research is needed in areas such as perception development, fusion, human factors, decision making and on reflecting C4ISR outcomes into military effects like maneuver. The "best of breed" philosophy (selecting the best of the existing algorithms) of JWARS and other simulation development efforts offers little promise that those models will meet the needs of the C4ISR analyst.

The working group spent a considerable amount of time discussing the relative advantages and disadvantages of four analysis approaches:

(1) Single monolithic campaign model that is responsible for representing everything.
(2) Hierarchy of models.
(3) Federation of models.
(4) Techniques other than simulation.

On balance the group supported the federation approach as having the most promise for analyzing the contribution of C4ISR on battlefield outcomes. The federation approach allows fidelity where fidelity is needed, and it allows the analytical team to review the cause and effect relationships as they unfold at the seams of the individual models. However, the approach still falls prey to such problems as aggregation/disaggregation, inconsistent model treatments and (VV&A).

The group discussed non-simulation methodologies such as spreadsheets, systems dynamics analytical models, wargames, exercises, historical analyses, surveys, man-in-the-loop simulations, but it felt that constructive simulations would continue to be the main tool for C4ISR analysis in the future.

4.1.3 Measures of Merit. The problem is not the definition of C4ISR MOPs or battle MOEs. Rather, it is the mapping of C4ISR MOPs into battle MOEs, the establishment of direct linkages between the C4ISR system performance measures and the criteria for mission effectiveness. The mapping is very dependent on context. Analysis requires multiple measures; no single MOP or MOE satisfies as a global metric for performance or effectiveness across all mission areas, nor is it a sound analytical practice to measure only a single attribute as the criterion in a study effort.

4.1.4 Scenarios. High level scenarios such as the Defense Planning Guidance (DPG) do not specifically address the totality of the variables associated with setting up an analysis. This requires the analyst to create portions of the scenario for a particular effort (e.g., specific force laydown, enemy behavior, own force ROE, etc.). All of these assumptions result in a multiplicity of scenarios eventually being created from what is believed by senior leaders to be a baseline from which all analysis efforts depart. Another serious problem with most scenarios is the fact that deployment timelines for C4ISR assets are rarely represented. Thus, C4ISR asset movements into theater are rarely accounted for — tending to overstate performance. The group also questioned if it was appropriate in today's environment to continue to focus on full blown MTW events rather than the more likely multiple smaller scale regional contingencies.

4.1.5 Experiment Design. There is a serious problem with the sheer number of variables to be considered in an analysis and the resulting overflow in dimensionality. The common approach to deal with the problem has usually been to reduce (somewhat arbitrarily) the number of variables for which the analysis will consider. In so doing, the analytical team runs the risk of not completely exploring the cause and effect relationships and dependencies between multiple variables. The trade-off is obviously time and money. More research is needed as to how one effectively manages the overflow in dimensionality. Unfortunately, most analysts lack an appreciation for the statistical issues around the experimental design and interpretation of analysis results.

4.1.6 Data. The group considered three types of data: system performance data, scenario data and behavioral data. They judged the systems data to be the most mature; however future systems data are lacking. Scenario data are incomplete in its representation of Red forces especially in terms of Red C4ISR systems and Red behavioral data. The existing data don't necessarily map into DPG scenarios. Another weakness is the absence of background data (civilian traffic, background communications load, etc.). The behavioral data is the weakest link. There are virtually no reliable data sources for C2 events that require decision making to occur or data that suggests what courses of action may transpire from equivalent battlefield events. Much research is needed for this area. The group felt it was necessary to have better standardization and cataloguing of data.

4.1.7 Human Factors and Organization. The group felt that this area was the weakest element. Behavior models are not developed; no Red behavior models are available; data for behavior and decision making are not available; human-in-the-loop approaches are not repeatable and may not be verifiable; and we don't know if we should model doctrine, "real-world," normative or optimal decisions.

4.1.8 Risk and Uncertainty. Uncertainty is often modeled with probability distributions. However, we don't understand the models, much less the distributions, much less the distributional parameters.

4.1.9 General Comments. Some of the most critical issues surrounding studies have little to do with the traditional analysis activities. Instead, they revolve completely around exogenous factors that frequently end up determining the results out of hand. These variables include the time allowed to complete the effort, the resources provided, the politics of both the question to be answered and the organizations chosen to run it (as well as those left out) and the expectations of the decision makers surrounding the results. These issues in a strict scientific sense should have no bearing on the results and yet they frequently are the first order effects that determine the answer.

4.1.10 The Bottom Line. Much basic research is still needed. The major deficiencies are:

- Linkage between C4ISR effects and campaign outcomes.
- Fusion.
- Perception development.
- Decision making.
- Basic combat itself (e.g., maneuver effects).

JWARS and other new model efforts are incorporating the "best" current algorithms — this approach will not work with respect to C4ISR. We recommend developing a prioritized list in the areas of C2, information fusion, communications, ISR, basic combat and C4ISR effects on combat. Use that prioritized list to direct the research plan. This research needs to be implemented in new model developments, but the effort should not be focused on a particular tool.

There are fundamental data gaps that hinder the ability to support C4ISR analyses. We recommend that the data requirements to support C4ISR analyses be identified, collected and made available to the analysis community.

C4ISR analysis will require a range of different models (it will not be limited to JWARS). There is still a serious need for additional development of the analysis infrastructure (to include data, scenarios, tools and experienced analysts) to respond to current demands.

4.1.11 Assessments.

Assessment of the Health of C4ISR Analysis for MTW

Element	*Aggregate Assessment*
Problem Structuring	Yellow
Human Factors/ Organization	Red
Scenarios	Orange
Measures	Yellow
Data	Red
Tools	Red
Risk and Uncertainty	Red
Report	Orange

4.2 Smaller Scale Contingencies (SSC) Working Group. In order to differentiate itself clearly from OOTW, the working group decided to focus its efforts on mission types in which the use of military force was likely (raids, hostage rescue, opposed Non-combatant Evacuation Operations (NEO), etc.). The missions were also viewed as those for which military considerations tend to take precedence over political considerations. The group recognized that this is an artificial distinction. Many formal definitions of OOTW explicitly include SSC. Moreover, SSC intended as nearly pure military operations often are changed into more political activities. The scenario played out in Haiti (which went in a matter of a few minutes from an invasion of a small country to a friendly

occupation with primarily political goals) provided a good example of this phenomenon. Finally, as the group stressed in its deliberations, SSC tend to have significant political dimensions, even when the operations themselves are largely military in character. The working group also concluded that analysis of SSC cannot be meaningfully conducted on the group of missions as a whole. Their diversity requires that tools and analytic efforts be focused on meaningful, coherent subsets of the topic. For example, studies of raids will require different tools and data than studies of hostage rescues. Meaningful analyses must have baselines for assessment of the contribution of current and future C4ISR systems, and the baselines do not exist for most of these mission types.

4.2.1 Characterization of C4ISR in SSC. The dominant requirement will be for more rapid and agile intelligence, planning and execution processes. This means exploring ways to improve the speed and responsiveness of the entire ISR process (from tasking through dissemination) as well as to couple situation awareness, decision making and execution more closely. SSC are different from MTW in that they almost always involve considerable pressure for centralized control. This arises both from the legitimate concerns of higher command arising from the potentially strategic implications of military activities down to the tactical level and the more idiosyncratic fact that SSC are often "the only game in town," which means that decision makers at all levels are free to invest time in them. MTW, on the other hand, are often large and complex enough that senior political and military officials often are too busy to focus on tactical level decisions and actions.

SSC may (but do not always) require a high level of tactical security (particularly in the planning, preparation and entry phases) and management of highly visible consequences. The experience of conducting an operation that is a military success yet fails in terms of US policy was all too familiar to the working group participants.

Communication issues arose several times during the discussion. SSC often require new or novel infrastructures that overcome gaps arising from military service differences, the need to include coalition partners or host nations, or the need to deal with non-military actors (inter-agency or NGO). Moreover, secure communications may be needed to achieve adequate operational security.

SSC are not necessarily a lesser-included case of MTW. This is crucial when data is being selected, models chosen, parameters estimated or research is being organized. Some of the distinctions were mentioned earlier. Others include the fact that the MOFE and MOPE are usually not under the control of the military. In this sense, SSC are properly understood to be OOTW. Moreover, the group stressed the fact that the intelligence required in many SSC is more fine grained and detailed than that required for the same levels of command in MTW.

SSC are often conducted under restraints that would not be present in MTW. Rules of engagement and political restrictions often limit the activities available for mission accomplishment. Moreover, SSC tend to be characterized by a very meaningful tension between efforts to avoid mission failure and maximizing the likelihood of mission success. Examples of decisions to limit the size and armament involved in operations in order to avoid undesirable political consequences were offered by several members of the working group.

4.2.2 Assessing Relative Worth. The method for assessing the relative worth of C4ISR systems was seen as readily available from fundamental operations research techniques. This is not to say that the data and tools needed to conduct those analyses are available. The group recognized the value of a particular C4ISR innovation could be seen as a function of the range of SSC missions to which it applies, the relative likelihood of those mission types and their estimated impact on the relevant MOFE and MOPE.

4.2.3 Measures of Merit. The group readily accepted both the set of measures of merit categories defined by MORS in the 1980s and the suggested change offered by Dr. Stuart Starr during his plenary address, of adding an outside layer, Measures of Policy Effectiveness (MOPE). This addition leads to the following hierarchy of measures: dimensional parameters, MOP, MOE, Measures of Force Effectiveness (MOFE) and MOPE. Equally important, the group also wanted to ensure that analyses of C4ISR in SSC "be informed by" metrics from all the relevant layers. Interoperability issues also arose several times. Metrics for interoperability and for information dissemination remains important in assessing future C4ISR systems.

The quality of the information available was seen as the single most important metric for SSC. This was defined to include its responsiveness to warfighters, including the Commander's Critical Information Requirements (CCIR), but also the needs of key staff members and the units executing the operation. Responsiveness was seen as including much more than mere availability.

What is meant by high quality information? "Perfect" information in a military situation is seen as complete (for the command's needs), current, correct, precise enough for the associated military purposes (which will vary from targeting, which is very precise, to general maneuver planning, which is often much less precise) and consistent. Consistent here means both internally consistent within the data, information and knowledge of the C4ISR system and consistent across command nodes.

Measures of merit that focus on rapid and robust decision making, planning and execution will be needed. This means we need valid and reliable indicators of the speed of the C4ISR processes, the variety of futures and alternative courses of action they can and do consider, and the quality of the decisions they make. Indicators of decision quality essentially must be MOFE and MOPE, though MOE for C4ISR, MOP for C4ISR systems and the dimensional parameters that drive them may also be needed for diagnostic purposes in any given analysis.

4.2.4 Tools. This area was perhaps the least mature of the areas discussed in the working group. The most important tool requirement was for credible support to Course Of Action (COA) analysis. This means tools that generate projections of alternative futures that are credible to operators as well as the capacity for sensitivity or "what if" analyses. These tools must also be fast enough to support mission planning and have an analytic mode that permits large numbers of runs in a short period of time. Moreover, these tools must be designed to pull from operational databases, not just notional or analytic ones.

Perhaps the most novel idea arising for new tools was a call for a virtual C4ISR rehearsal capability that would be designed both as a tool for analysts and for operators. Operators would use it for training and mission rehearsal. Analysts could use it for improving their understanding of missions, generating hypotheses about C4ISR improvements, examining man in the loop elements and testing hypotheses.

The group heard a similar plea for more effective ways to both link and differentiate real and simulated data, particularly in real headquarters participating in virtual exercises and training.

In general, tools are needed to assess the degree to which C4ISR systems are linked across functions, echelons and time. New information systems are linking operators more and more closely, but no tools to measure these changes or their impacts are currently available. Similarly, models that capture the effects of "soft factors" such as differences in language, culture or training are not available but would be valuable in an era that stresses "jointness" and coalition operations.

Analysts, particularly those supporting operational organizations, also felt a need to capture and replay information (data, voice traffic, imagery, etc.) for current and future operations. This would greatly facilitate after-action analyses from both operations and exercises.

4.2.5 Analysis of Four SSC Mission Areas. The group focused in detail on four different types of SSC mission areas to link future C4ISR needs, the analytical tools required to support their development, the most crucial measures of merit, and implied key metrics. The four mission areas were:

1. Raid.
2. Urban Warfare.
3. Counter Terrorism/Operational Disruption.
4. Opposed/Potentially Opposed NEO.

The discussions of measures was focused on MOFE and MOPE.

4.2.6 *The Bottom Line.* The current and future C4ISR needs for SSC must be addressed within the context of each specific mission category, as opposed to addressing a broad range of similar missions. By heeding this, proper analysis of each mission area may be secured. C4ISR data within SSC will need to develop a higher level of tactical detail and control then other arenas of warfare (i.e. peacekeeping, peace enforcement, major theatre war.) This characteristic, developed from tight operational constraints, will aid commanders' tactical planning, control and security. Investment in such C4ISR information systems such as virtual rehearsal programs, course of action analytical tools, and relational databases is recommended to increase military force flexibility and performance.

4.2.7 Assessments.

Assessment of the Health of C4ISR Analysis for SSC

Element	*Aggregate Assessment*
Problem Structuring	Orange
Human Factors/ Organization	Orange
Scenarios	Yellow
Measures	Orange
Data	Red
Tools	Orange
Risk and Uncertainty	Orange
Report	Red

4.3 Operations Other than War. As was done by the SSC working group, the OOTW Working Group began their deliberations by scoping the definition of OOTW to exclude any mission in which combat might be anticipated. The working group believed the fact that OOTWs are going on near-continuously offered the opportunity to focus analysis efforts on real operations — observe and analyze the operations as they occur. This reduces the need to build models and simulations.

4.3.1 Problem Decomposition. The OOTW group decomposed the problem. For a set of OOTW missions, they derived a set of typical functions within the missions and identified typical mission scenarios for analysis. For the scenarios, they considered how C4ISR means were employed in the mission. By crossing the C4ISR means with the mission functions, they identified the most interesting C4ISR evaluation issues. Finally, these led to a categorization of typical measures of merit and the appropriate tools to assess them.

The decomposition effort partitioned the problem into 12 major functions associated with OOTW missions: security operations, police operations, refugee operations, resettlement, compliance, inspection, surveillance, PSYOPS (Perception), civil affairs, sustenance, medical operations and governance. They then mapped the functions to the following subset of OOTW missions:

- Peace Keeping (PK)
- Peace Enforcement (PE)
- Peace building
- Humanitarian Assistance/Disaster Relief (HA/DR)
- Civil support
- Nation assistance
- Counter drug
- Counterinsurgency support

They then focused on two different missions: PK/PE and HA/DR and characterized each. This activity demonstrated clearly that the issues for the different missions were significantly different. For example, PK/PE focuses on

preventing conflict, restoring governance and stabilizing the situation, whereas, HA/DR focuses on stopping the suffering and dying. Similarly, there are different types of participants (coalition forces, civilian authorities, non-government organizations, etc.), levels of force, different data required and different measures.

4.3.2 Tools. The working group decided that many different types of tools would be needed to address the spectrum of OOTW missions. These include: Expert elicitation, polling, statistical analysis, data mining, wargaming, collaborative decision making, network analysis, functional capability models, learning from real-world activities, historical analyses, analytic frameworks and predictive capability models. Of course the group felt that the usual simulations would also be useful, but they would be less important for supporting analyses of C4ISR in the OOTW mission area than in those mission areas that focused on military operations.

While an end-to-end modeling approach in OOTW is well beyond the present state of the art, there is a clear need for tools and models that will do part of the job within the context of an analytic framework. For example, tools for HA/DRs that help to predict damage and casualties and generate requirements for medical supplies and personnel are needed. Within peace operations, models for assessing the performance of different ISR capabilities or communications networks would be helpful. Tradeoffs frequently will be based on expert judgment and will be qualitative rather than quantitative. In this area, qualitative trade-off judgments may be better than judgments based on trying to force the numbers to fit the problem.

Trades of C4ISR with forces for OOTW require better definition of missions and requirements, more organized exploitation of past lessons learned, databases of operational data, frameworks for analysis and appropriate supporting tools.

4.3.3 Measures. OOTW mission measures are known but may vary widely by mission. The measures are standard for many trades within C4ISR (e.g., command and control vs communications), but are very difficult for making tradeoffs between elements of C4ISR and forces. Certainly, by the nature of the mission, the measures needed for the latter tradeoff were not the usual attrition measures.

4.3.4 Recommendations. Establish an effort to advance our knowledge of OOTW and C4ISR in OOTW leading to best practices and analytic frameworks. Continue efforts to identify analytic tool requirements to assess C4ISR support to OOTW. Continue development of methods to better integrate OOTW analysis into DoD planning and programming. Establish a common syntax and semantics to facilitate a comparison between study results. Develop a deliberate approach to data collection (identify and prioritize needs, establish a mechanism for collecting data, establish repositories and include non-DoD sources.

4.3.5 Assessments.

Assessment of the Health of C4ISR Analysis for OOTW

Element	*Aggregate Assessment*
Problem Structuring	Orange
Human Factors/ Organization	Red
Scenarios	Yellow
Measures	Orange
Data	Red
Tools	Orange
Risk and Uncertainty	Red
Report	Orange

4.4 Peacetime Engagement Working Group. The Peacetime Engagement (PE) working group immediately came face to face with a definition problem. There is no current Joint Staff definition of PE. The group discussed the relationship between PE and overseas presence, and decided on the following definition which characterizes PE as deterrent in nature.

Definition: Peacetime Engagement is the application of resources (including forces) in

peacetime to make shooting less likely. Successful PE would promote other goals:

- Stability of commerce.
- Deterrence.
- Separation of potential belligerents.
- Exercises with (potential) allies.

Information superiority was judged to be the principal element of C4ISR implementation for the future. Successful management of information will depend upon development and establishment of joint doctrine, including processes and organizations.

4.4.2 Measures of Merit. The working group devoted much of its time discussing measures of merit. They partitioned the measures as falling into five categories:

1. Level of effort.
2. Task performance.
3. Mission progress.
4. Political goals.
5. Costs.

They discussed a variety of measures within each category, some of which were standard measures like number of reconnaissance flights flown and ISR reports delivered. However, many were measures unlike those used for combat operations. For example, the price of oil and the number of civilian truck deliveries. To a large extent the measure of success for a PE mission is the extent to which daily activities are routine.

4.4.3 Insights. The group discussions generated several useful insights about C4ISR analysis in the PE mission area. Some of the insights were:

- Information operations highest utility will be in PE.
- Intelligence Preparation of the Battlefield (IPB) is conducted during PE.
- PE is not a lesser included case of warfare.
- Coalitions are important; there will be greater numbers of potential partners in PE than in specific MTWs.
- Interoperability of C3I systems will be critical for PE because of the many potential partners.
- PE requires drawing in political constraints/considerations to a degree greater than for other mission areas.

4.4.4 Data. Like the other mission areas, the working group judged the availability of data to be a serious problem. The significant role of political constraints generates peculiar data requirements. Furthermore, the uncertainty about the probabilities of specific threats creates significant data collection and distribution needs.

4.4.5 Assessments. Because PE is not very well defined, the state of the practice for analysis related to any aspect of PE has many gaps.

Assessment of the Health of C4ISR Analysis for PE

Element	*Aggregate Assessment*
Problem Structuring	Yellow
Human Factors/ Organization	Yellow
Scenarios	Green/Yellow
Measures	Orange
Data	Orange
Tools	Orange
Risk and Uncertainty	Red
Report	Orange

4.5 Infrastructure Assurance. Since Infrastructure Assurance (IA) is a relatively new and evolving mission area addressing a new kind of warfare unlike what we have experienced in conventional warfare, the working group spent its initial discussions defining the mission area and being educated about recent Presidential and DoD activities related to the area. Following is the official definition of Critical Infrastructure Protection (CIP) (CIP and IA were considered to be synonymous) provided in the Presidential Decision Directive (PDD) 63, signed in May 1998.

4.5.1 Definition. Infrastructure assurance is the planning to improve the readiness, reliability and continuity of infrastructures such that they are:

- Less vulnerable to disruptions or attack.
- Harmed to a lesser degree in event of disruption or attack.
- Can be readily reconstituted to re-establish vital capabilities.

The DoD mission areas for IA are divided into 11 infrastructure sectors (3 of which comprise the C4ISR mission area): defense information infrastructure, command, control and communications, intelligence, surveillance and reconnaissance, public works, financial services, transportation, health affairs, emergency services, personnel, space and logistics.

The sectors cannot be considered in isolation; each is dependent on the others to achieve mission objectives. Since these services are routinely provided by commercial assets outside the government sector, the focus of analysis must broaden to include law enforcement, Other Government Agencies (OGA) and the private sector. The dependencies among the sectors must be well understood for analysis.

4.5.2 DoD Approach to Infrastructure Assurance. The draft DoD CIP Plan states that the approach to IA is to:

- Identify relevant characteristics of each infrastructure that is critical to military mission success.
- Analyze military plans to identify critical infrastructure assets.
- Assess vulnerabilities of critical DoD assets.
- Redirect resources to reduce prioritized vulnerabilities.
- Collaborate with other government agencies and the private sector to reduce vulnerabilities when services are provided from outside the DoD fence.

The above steps are conducted in the context of six lifecycle phases that occur before, during, and after events which may compromise or disrupt the services or mission accomplishment of a critical infrastructure:

- Analysis and assessment (preventive).
- Remediation (preventive).
- Indications and warning (before an event).
- Mitigation (before and during an event).
- Response (during an event).
- Reconstitution (after an event).

4.5.3 Data. Operational architecture data on organizational missions, functions, structures, systems and their relationships to include information flows and dependencies are needed. This presents unique problems because much of the needed data must come from the private sector and are proprietary. Much inter-agency information sharing is needed to satisfy requirements. The MDITS database for counter-terrorism is one example of a database that must be shared with the IA community.

4.5.4 Analysis Tools. Current DoD analysis tools generally lack the capability to facilitate detailed IA analysis because C4ISR requirements generally have not addressed the need to support IA. IA tools have been developed in response to IA community requirements and are effective for analyzing commercial infrastructure and the military missions that they support. Integrated and interoperable tools or comprehensive models for analyzing defense infrastructures are non-existent. Likewise tools to conduct interdependency analyses are non-existent. Some of the tools that are used for analysis supporting IA are the Joint C4ISR Architecture Planing/Analysis System (JCAPS) and the NCS for communications. For cyber infrastructure, the NIPC and various Certs are C4ISR components that support analysis and assessments. Wargaming is frequently used to better understand the problems and issues.

4.5.5 Measures of Merit. The working group suggested a hierarchy of measures of merit for IA and its dependence on C4ISR as a basis for mission success and national security. The hierarchy (from top to bottom) is:

- National security.
- Missions (DoD and other).
- IA functions.
- C4ISR systems performance.

4.5.6 Issues. Some of the major issues identified by the working group are:

- Getting governmental entities within DoD and other Federal, state and local agencies to share information (which is sometimes proprietary), to share costs, and to have a common understanding of IA.
- Fidelity of data.
- Getting the commercial sector to provide proprietary data.
- Developing a central data repository.
- Security and privacy issues.
- Legal issues.
- International cooperation.

4.5.7 Recommendations. The group made two recommendations:

1. MORS continue to emphasize IA as an essential element of C4ISR (and other) analyses and wargaming and simulation exercises.
2. MORS and the IA community begin to develop mutual understanding of the requirements of IA analysis requirement in order to develop integrated or complementary tools.

4.5.8 Assessments.

Assessment of the Health of C4ISR Analysis for Infrastructure Assurance

Element	*Aggregate Assessment*
Problem Structuring	Yellow
Human Factors/ Organization	Red
Scenarios	Red
Measures	Red
Data	Red
Tools	Red
Risk and Uncertainty	Red
Report	Red

4.6 Information Architectures. The Architectures working group was included as part of the workshop because of the increasing emphasis and importance of operational and systems architectures for information systems to the C4ISR analyst. Analytical paradigms have traditionally focused on evaluating the effectiveness of a platform or system. Architectures provide a structured approach for describing and understanding a system-of-systems associated with a specified domain, such as C4ISR. In so doing, this allows that domain to be considered as if it were an entity. Using the architecture construct enables our analytical focus to evolve from being platform-centric to being architecture-centric.

Architectures are still an evolving discipline which demands a combination of both art and science. They help us understand the relationships and dependencies among tasks, operational elements accomplishing those tasks and the information flow that needs to occur among the operational elements to accomplish the tasks appropriately. They enable us to describe the systems and communications that support the information flow across nodes and, in so doing, enable the understanding of how information technology supports work. The architecture descriptions form the basic data set of activities, operational elements, information flows, nodes, systems and communications that support a wide variety of C4ISR issue analyses.

An architecture should not be viewed as an end in itself, but should be a means to an end. Operational architectures can capture operational requirements in a fashion that allows consistent traceability to design specifications.

4.6.1 Keys to Realizing the Potential of Architectures. The group discussed several things needed to realize the potential of architectures. The keys are summarized below:

- Must be able to access, manipulate and reuse data across a wide range of stakeholders to include developers, users and acquirers.
- Must be able to integrate human factors into the information architectures. People are an integral part of any information architecture.
- Need to represent the threat more overtly to include analysis of adversary as well as friendly.
- Better tools are needed (better visualization tools, more flexible tools, more usable by the operational subject matter experts).
- Must be able to better articulate the operational impacts of architectural analysis to warfighters and to decision makers.

4.6.2 Measures of Merit. Measures are needed for information architectures to quantify the relationship between measures of performance and operational measures of effectiveness. Measures are also needed to evaluate an architecture. Three aspects that could be measured are:

1. How well the architecture description has been developed.
2. To what extent is the architecture description being used.
3. The value of the architecture in achieving C4ISR goals and objectives.

4.6.3 Assessments. Because information architectures do not represent a mission area, the standard COBP for evaluating the health of C4ISR Analysis is not as relevant for architectures as it is for a mission area. Nevertheless, the architectures working group provided an assessment (with perhaps some differences in the interpretations of the elements).

Assessment of the Health of C4ISR Analysis for Information Architectures

Element	*Aggregate Assessment*
Problem Structuring	Green
Human Factors/ Organization	Yellow
Scenarios	Yellow
Measures	Red
Data	Yellow/Orange
Tools	Yellow
Risk and Uncertainty	Yellow
Report	Red/Orange

4.7 Analytical Techniques and Tools. Even though each of the other working groups addressed the issue of tools to support C4ISR analysis within a specific mission area, MORS had a separate working group focusing specifically on analytical techniques and tools for C4ISR analysis. The group discussed a variety of methodologies to include simulations such as JWARS, network analysis models such as NETWARS, optimization tools, systems dynamics models and Complex Adaptive Systems (CAS). However, the focus was on the workhorse simulation tools.

4.7.1 Taxonomy of Decision Issues. In order to structure the assessments and to facilitate communication, the working group developed a taxonomy of decision issues. The taxonomy partitioned the C4ISR analysis problem along three dimensions according to the category of decision issue (force structure, cognitive behavior, CONOPS, architecture, vulnerabilities, trade space), the decision maker (acquisition, operational, POM/budget) and scale of conflict (MTW, SSC, OOTW). Then, within each element of the cube the working group developed a qualitative assessment of the ability of existing tools and techniques to support C4ISR analysis. This qualitative assessment considered tools and techniques in aggregate (simulations, optimization, CAS, systems dynamics, game theory, etc.) and considered a variety of evaluation criteria (scenario, data, human behavior, maturity,

measures, etc.). For many of the cells (combinations of decision issue by decision maker by mission area, comments were provided to explain the reasons for the assessment. The number of combinations are too voluminous to be presented in this summary; however we will provide some general observations based on the evaluations. See the briefing slides from the Analytical Techniques and Tools Working Group in the Appendix for the all of the evaluations provided.

All of the assessments for the operational and acquisition decision makers were either yellow or red (no green). The situation was judged to be somewhat better for the POM decision maker with a sprinkling of green assessments for the CONOPS decision category and for force structure (the area where we have the most experience) under the MTW mission area. The most frequent explanation as to why an evaluation was rated yellow or red was a problem with data.

4.7.2 The Sky is Not Falling. Even though the evaluations of the existing analytical techniques and tools painted a bleak picture as to providing support to the C4ISR analysis community, the group emphasized that the story is not as bad as it may sound. There are some promising new analytical techniques; there are some promising new simulation development efforts; and there is a good core of analytical talent.

4.7.3 Recommendations. The working group was optimistic that the problems could be fixed with additional attention. Specific recommendations were to:

- Continue to fund research and development in the applications of current methods and new tools.
- Refine joint analysis tools.
- Train analysts to do analysis of joint issues.
- Emphasize more effective ways to explore the scenario space.

5. CLOSING COMMENTS

This workshop purposely sought out individuals who were not among the "usual MORS workshop attendees" for the express purpose of seeking out fresh new ideas about C4ISR analysis. To a large extent the memberships (and the chairs) of the Information Assurance and the Information Architectures Working Groups were comprised of people who were not regular MORS workshop attendees. There was widespread agreement that this expanded membership contributed greatly to the success of the workshop. Thanks should go especially to the chairs of those working groups: Mr. Thomas Bozek and Mr. Frank Ruggeri for Information Assurance and Ms. Patsy McGrady for Information Architectures. MORS should continue the practice of seeking out "new blood" for workshops.

Spectrum of Analysis Techniques. Analysts will always have to rely on clever, innovative use of the entire spectrum of evaluation techniques. Table 5 depicts the most common techniques and characterizes each according to resources, lead time, breadth of application, replicability and credibility. It shows seven classes of techniques ranging from expert elicitation to real crises and combat. A mix of tools will generally be required to compensate for the shortfalls of individual tools and to adequately represent Blue and Red processes.

Table 5. Spectrum of Evaluation Techniques.

Technique	*Resources*	*Lead Time to Create and Apply*	*Breadth of Application*	*Replicability*	*Credibility*
Expert Elicitation	Lowest	Days-Weeks/ Days	Very Broad	Limited	Variable
Wargame	Low	Weeks/Days	Very Broad	Limited	Fair
Analytical Models	Low	Weeks/Days	Broad	Fully	Fair
Constructive Simulation	Low-Moderate	Months/Days	Broad	Fully	Moderate
Virtual Simulation	High	Years/ Months	Moderate	With Difficulty	Potential for Good
Live Simulation	High	Years/Weeks	Limited	Little	Generally Good
Real Crises/ Combat	N/A	N/A	Quite Limited	None	Excellent

A mix of tools will also be necessary to pursue an iterative approach to C4ISR analysis. The set of techniques appropriate for a broad and shallow initial cut at the problem will be different from the techniques appropriate for subsequent narrower and deeper cuts at the problem. In the early stages, the techniques will tend to be those at the lower part of the spectrum (expert elicitation, wargames, analytical models). Quick and inexpensive techniques will be needed to efficiently explore the scenario space, to determine what are the critical parameters and to design the analyses that will follow in the later stages. In the later stages, the techniques will tend to be more resource intensive constructive, virtual or live simulations.

5.2 Comments on the Self-Assessments. The COBP template proved to be very useful for focusing discussions during the workshop. The assessments of the working groups about the health of the state-of-practice for C4ISR analysis were not encouraging, but I suspect that we tended to be overly pessimistic in our assessments. Yes, many improvements are needed — particularly with respect to human factors, scenarios, data and analysis tools. However, there was little mention during the workshop of perhaps the most important element in the conduct of good C4ISR analysis — *the analyst*.

5.3 The Importance of Good Analysts. We need to keep in perspective that even good tools and data and scenarios do not guarantee good analyses. Instead, good analyses result from:

- The ability to parse a problem down to its essence.
- The ability to synthesize the diverse parts of a problem.
- Domain expertise.
- Availability of analysis tools (including data and scenarios).
- Knowledge of the tools and the craft of analysis.
- Experience on the job.
- Knowledge of military operations.
- Good communications between the analyst and the consumer.

Most of the above requirements for good analyses point to the need for good, experienced analysts. Analysts knowledgeable about their tools can frequently figure out ways to make good use of the available tools. Good analysts can make innovative uses of tools to address questions that the tools were never designed to address. If good tools are placed in the hands of good analysts, the combination is unbeatable.

Gary Federici, CNA, stated in his response to my inquiries about tool to support C4ISR analysis a few years ago:

> *I have an uneasy feeling that many of those who are involved in all this are not clearly aware of some crucial truths about modeling. There is a widespread perception, I believe, that a model is a black box which accepts assumptions on the input side and reports outcomes as output. ... What relatively few people reflect on, from lack of direct experience in or study of campaign analysis, is that within the black box sit a group of analysts who pull its levers and turn its dials and have a very major influence on its outcomes.*

It is absolutely essential that DoD pay as much (or more) attention to developing and retaining good analysts. In the words of Dr. Stuart Starr, DoD needs to develop an "intellectual reservoir" upon which to base future C4ISR analysis activities. Such a reservoir will require a continuing, highly capable, multidisciplinary team with access to all of the relevant information. The C4ISR Decision Support Center is one model of a government-run organization. Another potential organizational model is the Phase One Engineering Team (POET), which draws on personnel from FFRDCs and not-for-profits to support analyses of ballistic missile defense issues.

5.4 Some Encouraging Signs. In spite of the many deficiencies in the C4ISR analysis area, there are several encouraging signs. First, the analysis community realizes that there are many deficiencies and that steps need to be taken to remedy the deficiencies. High-level decision makers are aware of the deficiencies, and they seem willing to invest the resources to address the problems.

Secondly, efforts are already underway to remedy some of the deficiencies. For example, JWARS, NSS, NETWARS and the C4ISR Federation are all major programs to develop improved decision support tools. The M&S community is beginning to understand that a new paradigm in modeling is necessary with explicit consideration given to modeling the information and decision processes, joint operations, communications, fusion and perception management. However, this workshop has pointed out that no single framework, no single tool, no single measure was sufficient to deal with the full set of issues of interest. The challenge is to select and orchestrate the needed tools and measures to reflect the substantive issues in question and to be responsive to the needs of the decision makers.

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Analyzing C4ISR for 2010 Major Theater War

Major Theater War:
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Dr Mark Youngren, Co-Chair

Major Theater War:
Working Group Agenda

- **Tuesday Afternoon:**
  - **1300-1430 Introductions and Opening Remarks (3-5 Min. per person)**
  - **1500-1530 Chair stakes out mission and ROE**
  - **1530-1630 Problem Articulation For Next Day**
- **Wednesday Morning**
  - **0800-0900 Analysis of the Current State of the Art**
  - **0900-1000 New Methodologies and Tools**
  - **1000-1100 Requirements for C4ISR Analysis**
- **Wednesday Afternoon**
  - **1230-1330 Synthesis of Morning**
  - **1330-1600 Recommendations**
  - **1600-1630 Wrap-up**
- **Thursday Morning**
  - **0800-1000 Recap/ New Topics**
  - **1000-1200 Write Up Findings As Group**

Major Theater War:
Approach

- **What is the Scope of this Working Group?**
  - **Definitions**
- **What is the current State of the Art?**
  - **Models**
  - **Analysis**
- **What are the appropriate tools to "give DoD the capability to do C4ISR Analysis?"**

Approach:

The approach detailed on this and the next slide were developed beforehand by the working group co-chairs. The group agreed to follow this general approach.

Major Theater War:
Approach (cont'd)

- **What are the requirements for C4ISR Analysis?**
  - **Models**
  - **Data**
  - **Analysis architectures**
  - **Supporting infrastructure**
- **What are the recommendations for the Workshop Sponsors?**
- **The Bottom Line**
  - **Outbriefing**
  - **Final report**

Major Theater War:
Scope of the Working Group

- **Consider issues related to producing analysis in support of major DoD programmatic decisions (e.g., QDR)**
  - **Analysis of C4ISR programs and issues (e.g., CONOPS, interoperability)**
  - **Analysis of other programs and force structure in JV 2010, to include shortcomings**
- **Examine how we can do the analysis, which includes, but is much more than, developing models of C4ISR**

Scope of the Working Group:

The first substantive task of the group was to reach a consensus on what matters were properly within the purview of the group, and what matters were not. The group agreed that the focus would be on the use of C4ISR analysis and tools to support major programmatic decisions such as the QDR. This would include the analysis of C4ISR systems in the context of total force structure, but would also include the representation of C4ISR in the analysis of force structure and military sufficiency, again in the context of QDR-like analysis. The proper use of C4ISR analysis and models in support of CINC COA determination (in particular CENTCOM and USFK MTW modeling) was considered to be outside of the scope of the group.

Some particular comments and issues raised by the group in this discussion were:

- Is an MTW scenario enough to make statements? The DPG IPS are useful to size the force structure but not necessarily the ISR component; ISR issues usually require "fleshing out" the scenarios. The DPG IPS are useful to size the force structure but does not necessarily cover totality of capabilities required
- There is a need to model Red behavior in as much detail and fidelity as Blue behavior.
- Who is the Decision Maker? In general, the SECDEF/Congress (e.g., QDR), but CINC requirements were included in subsequent discussions. Specific Decision maker is usually the DepSECDEF/VCJCS.

Major Theater War:
Current State of the Art (Summary)

- **Legacy Combat Models**
  - **Scripted C2, some rule set behavior**
  - **Some communications but simplistic**
  - **Little effect shown from attacking C2**
  - **Deterministic intelligence with little quality reference**
  - **Limited explicit representation of C4ISR systems and mapping into combat outcome**
  - **Sensor collection models may be adequate**
  - **Intel and Combat models stovepiped**

Current State of the Art (Summary); (Slides 7 and 8):

These two slides were prepared beforehand by the co-chairs. There was some discussion and disagreement over specific items on the slide, but the group agreed to the words that appear on this final version. Some specific comments:

- Current (legacy) models aren't all bad; modeling and analysis work to date have some useful attributes. However, in general, the state-of-the-art is woefully lacking in representation of C3 issues. ISR collection attributes are fairly well understood. Most importantly, the cause and effect of information on battle are not well understood or treated with existing models.
- It is necessary to differentiate between a single model and a federation of models. The advantages and disadvantages of various approaches are discussed in later slides.
- Battle outcome as function of maneuver (e.g., flank attacks) are not well treated or understood.
  - The impact of information on C2 function is currently based on timeliness; the quality of the information available for changing decisions is not considered.
  - In legacy models, doctrine is hardwired.

- Red C2 is needed to be reactive to Blue decisions, to show impact of Blue C4ISR.
- The impact may be dampened by red "inertia" in present analysis (i.e., Red follows same plans regardless of Blue capabilities).
- Communications physics is understood and **can be** modeled if desire is there.
- Communications are usually ignored because of the laborious and time consuming issues associated with the details of such efforts. The community has ignored the impact of these assumptions.

Major Theater War:
Current State of the Art (Summary)-cont'd

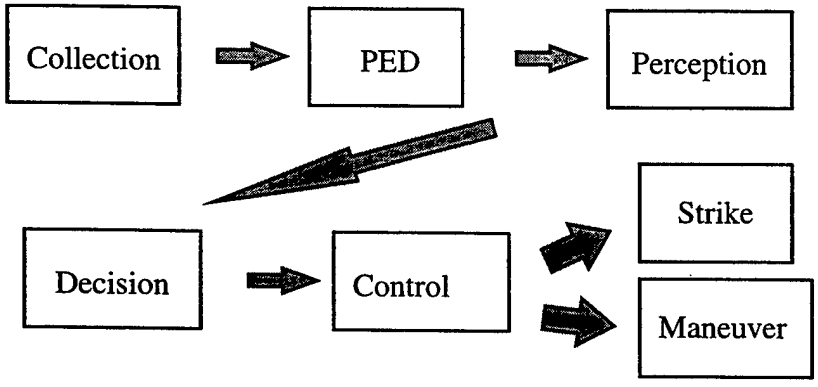
- **Campaign models under development - still no theory**
  - **Still much scripting**
  - **Using present models as basis, we still don't have good C4ISR process representations in many areas**
  - **Rule set behavior**
  - **Stochastic intelligence but simplistic fusion**
  - **Mixed effect shown from attacking C2**

Major Theater War:
State of the Art

- **Collection Modeling**
  - **IMINT --- Good**
  - **ELINT --- Poor due to emissions not well modeled (scenarios)**
  - **COMINT ----- Scripted to Zero (emissions)**
  - **Cross Cueing --- Poor**
  - **MTI --- Marginal (Red Behavior)**
  - **MASINT -- Non-imaging IR OK, the remainder non-existent**
  - **HUMINT --- Humans????**
- **PED Models**
  - **Good representation of time and volume flows**
  - **Poor representation of content (information vice data)**
  - **Dissemination and representation of organizational (hierarchy) knowledge poorly represented**
- **Fusion Models - non existent**

The State of the Art:

The group decided that it would be useful to break up the ISR and C4 process in order to assess specific capabilities and deficiencies in the state-of-the-art representations of this process in current models. The following diagram was used:



The assessment was then made on various aspects of the C4ISR process within each box. In general, collection modeling was regarded as good overall (with specific deficiencies in some areas such as HUMINT, for example). PED models of total flow are mature but lack consideration of the quality of information, which is essential to answer the "so what?" response to volume measures. Fusion models are essentially non-existent, in real world as well as in analytic modeling. Obviously, some correlation and filtering is done in the real world but this automated process is regarded as immature.

Major Theater War:
State of the Art (cont'd)

- **Decision Modeling**
  - **Rule set construction well understood**
  - **What rules to use, especially in the future (different doctrine, CONOPS) not available**
  - **Human factor issues not understood**
  - **What decisions to model? Doctrine, "real world", normative, optimal?**
  - **Strike decisions / resource allocation relatively well understood, maneuver issues and effects not well understood**
- **Perception**
  - **COP representation does not reflect quality of information, the degree to which different sources agree/disagree, or alternative hypotheses**
  - **If the COP has an area with no Red, is that because we have extensively observed the area and seen no Red, or is it because the area is obscured from view, or is it because we haven't looked there?**

The State of the Art (Continued):

Decision and perception modeling are also immature. Even if the process of representing a decision is known (e.g., rule-based inference), what decisions to use is up in the air. Unfortunately, the choice of decisions(s) to use in models often dominates the model outcomes, having an effect much greater than that realized by changes in systems or forces. Do we have the data to determine when decisions are made and how good they would be? Decisions should be evaluated as a function of risk based on the amount of information available, not necessarily the outcomes (hindsight). It is possible to make decisions that are "bad" from the view of the outcome but "good" with respect to the information available at the time that the decision was made.

Major Theater War:
State of the Art (cont'd)

- **Communications**
  - **Communications network modeling relatively well understood**
  - **Physics well understood but not necessarily included**
  - **Bandwidth and legal issues not represented**
  - **Time and volume analysis moderately well understood**
  - **Often don't do the communication modeling we understand because of time and data constraints**
  - **Often done off-line but this inhibits dynamics**
  - **Difference between passing data (connectivity, delay) and passing information not understood**
  - **Impact of loss of communications on C4ISR (which in turn effects battle outcomes) not well understood**
- **Planning / Re-planning**
  - **Plan execution and development relatively well represented**
  - **Re-planning poorly represented if at all**

The State of the Art (Continued):

Communications modeling (physics based) is well understood; the modeling of information flows (vice bits per second) is not. Automated planning and re-planning capabilities are also lacking. ISR (collection) planning is easier because much is preplanned, but on the fly NAI's are not done.

Major Theater War:
State of the Art (cont'd)

- **Combat Outcomes**
  - **Strike relatively well understood**
    - **BDA and re-planning not as well understood**
  - **Maneuver not well understood**
    - **Even if we do C4ISR well, impact may not be reflected. E.g., what if we attack Red C4ISR and surprise him? What is the effect of surprise?**
    - **Representing the effect of maneuver on Red behavior not understood (e.g., causing Red to withdraw without actually attacking him).**
  - **Total Force Protection and Focused Logistics are buzzwords with respect to C4ISR impacts**
    - **Limited functions (e.g., TMD) are reasonably well represented**

The State of the Art (Continued):

Basic research is still needed in basic combat effects modeling. C4ISR capabilities should enhance maneuver, for example, but the effect of that maneuver is not well represented in current attrition-based models. There are two issues here. Our basic inability to tie Situational Awareness to a decision in a predictive manner means that we can not then link the decision to a battle outcome. The second issue is that most, if not all, ground combat models are insensitive to time and space of attack and what they mean to success. Therefore we can neither predict accurately what a commander would do differently as a result of information or show how that difference in movement or timing resulted in a change to his probability of success. As long as battle outcome metrics (casualties, force exchange ratios, etc.) are used to measure the effectiveness of new systems (to include C4ISR systems) and forces, better representations of basic combat effects will be required. Some specific observations:

- Models are insensitive to outcome based on first order effects; this is much more acute in maneuver
- There is little cross representation; e.g. Strike and IO impact on maneuver.
- Legacy Models have good physics for movement and for some outcomes.

The bottom line:

- Campaign models are desired by decision makers -- MOFEs are preferred.
- It is necessary to move away from FER to representing maneuvering effects logistics, strategic effects, time to achieve objective, fratricide, IO, etc.
- Current models all have significant/critical deficiencies for C4ISR analysis; some have partial capabilities
- Major problems lie in combat modeling as well as in C4ISR models and integration

Other areas of deficiencies:

- Non-Combat
- Red C4ISR
- Red ROE decision heuristics
- IO
- Other Coalitions

Major Theater War:
Requirements for C4ISR Analysis

- **Analysis Set Up**
  - **Problem Definition**
  - **Experimental Design**
  - **Risk and Uncertainty**
  - **Tools**
  - **Scenarios**
  - **Assumptions**
- **Data**
  - **Sources**
  - **Assumptions on data**
  - **Aggregation**
  - **Missing Data**
  - **Incorporating Judgement**
  - **VV&C**

Requirements for C4ISR Analysis: (slides 13 and 14)

These slides are just meant to set the stage for those topics that we discuss in detail over the next 10 slides.

Major Theater War:
Requirements for C4ISR Analysis (cont'd)

- **Tools and Methodologies**
  - **Single campaign model (e.g., TACWAR, JWARS)**
  - **Hierarchy of Models**
  - **Federation of Models**
  - **Non-Simulation Tools**

Major Theater War:
Analysis Setup

- **Problem Definition**
  - **More is Better?**
  - **Defined Objectives**
  - **Constraints? Casualties**
  - **Time and Resources**
- **Types of questions**
  - **What is best among alternatives?**
  - **How much better is A than B?**
  - **How much A do I need?**
  - **What is the tradeoff between A&B?**
  - **How does A effect ....?**
  - **How much does A cost?**
  - **How well does A perform?**
  - **Identify Offsets**
  - **What is the marginal return of A in combat metrics?**

Major Theater War:
Problem Definition – Drivers

- **Time**
- **Resources**
  - **People**
  - **Money**
  - **Available Model**
- **Question**
- **Politics**
- **DM Expectations**
- **DM Focus**
- **Security Considerations**
- **Coalition Considerations**
- **Data Availability**
- **Scenario Availability**
- **Culture**
- **Previous Studies**

Problem Definition:

Some of the most critical issues surrounding studies of this magnitude have little to do with what may be called the classical design features of the scientific method. Instead, they revolve around completely exogenous factors that frequently end up determining the results out of hand. These variables include the time allowed to complete the effort, the resources provided, the politics of both the question to be answered and the organizations chosen to run it (as well as those left out), and the decision maker's expectations surrounding results. These issues in a strict scientific sense should have no bearing on results and yet they frequently are the first order effects that determine the answer.

Of the remaining issues the concepts of clearly articulating the question and working with the decision maker to insure that the question is properly understood by all and framed such that an answer can be derived is the most meaningful part of the analytical process. Scenarios, data and past work are all acknowledged as both required and unevenly provided and exercised in most study efforts.

Major Theater War:
C4ISR MOEs

- **Definition of C4ISR MOPs and Battle MOEs not the problem.... It is the mapping of C4ISR MOPs to Battle MOEs**
- **Very Dependent on Context**
- **Analysis requires multiple MOEs**

MOEs:

The definition of C4ISR MOPs is not a problem within the community from the perspective of the group. Nor is there difficulty in establishing criteria for mission success, e.g. MOEs. The real issues continue to be the ability of the analytical community to confidently establish direct linkages between the C4ISR system performance measures and the criteria for mission effectiveness.

It is noted that no single MOP or MOE satisfies as a global metric for performance or effectiveness across all mission areas, nor is it sound analytical practice to only measure a single attribute as the criterion in a study effort. In studies as large and complex as those involved with MTW multiple criteria are required.

Major Theater War:
Scenario and Excursions

- **Deployment Timeline /Force Structure for C4ISR assets not represented**
- **Baseline Typically Directed**
  - **Problems:**
    - **Multiple Detailed Versions of DPG Scenarios Exist**
    - **Multiple Predictions of Future, Conflict Areas**
    - **Little Definition of Red/Allied beyond initial lay down**
- **Should we vary Scenarios? How much?**
- **Red Scenario should be dynamic not fixed**

Scenarios and Excursions:

There are two issues embodied in this slide. The first issue is the fact that rarely, if ever, are C4ISR asset movements into theater accounted for. The second issue is that high level scenarios such as the DPG do not specifically address the totality of the variables associated with setting up an analysis.

The first issue results in unrealistic assumptions about C4ISR assets in theater early in a campaign and because of this likely overstate performance. The second issue requires the analyst to create portions of the scenario for a particular effort (e.g. specific force laydown, enemy behavior, own force ROE, etc.). All of these assumptions result in a multiplicity of scenarios eventually being created from what is believed by senior levels to be a homogenous baseline from which all efforts departed.

Other concerns revolve around the issues of whether, in today's environment, it is more applicable to analyze full blown MTW events rather than multiple Smaller Scale Regional Contingencies.

Major Theater War:
Experimental Design

- **Classical designs often not useful because statistical model not appropriate**
- **Too many things that should be varied - judgement on what needs to be varied**
- **Answers tend to be multidimensional; combination (via MAU?) often not well defined or explained to DM**
- **Exploratory analysis and prescreening may be useful**
- **Context dependent**

Experimental Design

A review of recently completed analyses made in the context of an MTW shows that basic problems exist in terms of the sheer number of independent variables that can impact results. This "overflow of dimensionality" results in an experimental design that is unmanageable. The way recent efforts have dealt with the issue is to somewhat arbitrarily reduce the number of variables for which the analysis will study the impact. In so doing, the analytical team runs the risk of not completely exploring the cause and effect relationships and dependencies between multiple variables. The trade-off for this is obviously time and money. In general the group felt that more research needed to go into how to effectively manage this effort and maybe research that would provide insight into the variable dependencies that would allow constrained-run matrices in the future.

Unfortunately, many analysts lack an appreciation for the statistical issues around the experimental design and interpretation of analysis result. For example, many of the packages and statistical techniques rely on assumptions such as normality and homoscedasticity, which are usually not tested for. Another example is the dearth of statistical tests for ordering means (vice determining if they are different).

Major Theater War:
Data

- **Few Accepted Sources for C4ISR Data**
- **Red C4ISR/Behavior data lacking**
- **Human Performance data lacking**
- **Hard to generate data for poorly understood models**
- **Future systems data lacking**
- **Existing models haven't generated requirements for this type of data, therefore no one is tasked/funded to gather it**
- **Recording/cataloguing data from other analyses is necessary**

Data:

The discussion here centered on the distinctions between system performance data, scenario data, and "behavioral" data (e.g. human decision making). Although there are always issues of how to characterize future systems and difficulties in getting some organizations (e.g., NRO) to share data, the group felt that MTW was the most mature area of data collection and storing in the community. There are several organizations that are chartered to collect and hold such information for general use and it is also the most easily understood data within the non-modeling community. The next layer of data, scenario data, has many problems associated with it. As alluded to above, multiple analyses seem to beget multiple interpretations of proscribed "baselines". In addition this type of data is incomplete in its representation of red forces especially in terms of Red C4ISR systems and Red Behavioral data. The final and most vexing area of data required is that on behavioral entities. There are virtually no reliable data sources for C2 events that require decision making to occur or data that suggests what courses of action may transpire from equivalent battlefield events (Red or Blue). The group felt that in order to advance the science of C4ISR modeling much research was required here, followed by the nomination of a group or organization to manage and store the results.

Major Theater War:
Data (Continued)

- **Existing data doesn't necessarily map into DPG scenarios**
- **Big difference between physical data and behavioral data**
- **Background Data (civilian traffic, etc.) not available "Baseline" Data hard to define when C4ISR changes can change scenario, decisions, behaviors**
- **Scenario Data developed for unique modeling constructs**
- **Security Issues**
- **Politics/Data Sharing**

Major Theater War:
Methodology/Tools

Monolithic Single Campaign Model

Effective Use:

- **Calculates MOFE**
- **Full context of conflict**
- **Demonstrate what you already decided**
- **OP Plan Analysis**
- **Combine with higher-level models to explore particular issues**

Problems:

- **Theoretically Flawed**
- **Tend to focus on attrition**
- **Very complex and data intensive**
- **We are building a tool based on today's understanding of C4ISR impacts, while no one really knows the true mechanisms by which C4ISR impacts battle**
- **V&V with evolving models**

Models and Tools:

The group examined four major approaches to representing C4ISR systems in the context of an MTW campaign analysis. These approaches were:

- Developing a single, monolithic campaign model that represents "everything,"
- Developing a hierarchy of models,
- Developing a federation of models, and
- Using nontraditional techniques outside of simulation.

Pros and cons of each approach were discussed.

***Monolithic*:** There are two major points that need to be brought out when looking at large campaign level monolithic models. The first is that they are by their nature low fidelity representations of the combat and combat interactions, as such it is extremely hard to identify cause and effect relationships for those features that are not explicitly designed into the model as a major driver of combat results. Given that this has never been done for C4ISR it is next to impossible to use such models today to adequately address the impact of information. The second issue is that it will only be possible in the future if the theory of C4ISR impact on battle operations is canonized and put into these models as a first order driving effect.

Another observation not well appreciated by senior decision makers is the fact that current C4ISR-based advanced modeling efforts (e.g., JWARS and JSIMS) will not provide any better representation of C4ISR systems and processes that the current (poor) state-of-the-art allows unless research (vice coding) is invested in.

Major Theater War:
Methodology/Tools (Continued)

Hierarchy of Models

Effective Use:

- **Data generation for low-res models**
- **Determine what issues to look at**
- **"Flesh Out" detailed issues**
- **Cross-check "validity"**
- **Depth and Breadth**

Problems:

- **Aggregation/Dissaggregation**
- **Model treatments often inconsistent**
- **Confidence Intervals ...Accuracy measures across multiple models**
- **Choosing what to represent at higher resolution**
- **Multiple answers to DM**

Hierarchy:

This approach has one main draw back. Data is usually modeled at different levels of fidelity across the continuum of the modeling structure. Whether it is the data used to created the scenario or the data used in treating impacts of various attributes of the war they are probably considered in differing degrees of fidelity and therefore the linkages of models becomes suspect.

Major Theater War:
Methodology/Tools (Continued)

Federation of Models

Effective Use:

- **Accepted Models do Exist**
- **Treats Individual Functions in Higher Fidelity than Campaign model allows**
- **Insures Cause and Effect Explicitly Treated and Understood**
- **Data generation for Combat Models**
- **"Flesh Out" detailed issues**
- **Cross-check "validity"**
- **Depth and Breadth**

Problems:

- **Target Domain mapping**
- **Aggregation/Dissaggregation**
- **Time and Space Discontinuities**
- **Model treatments inconsistent**
- **Feedback loops lacking**
- **Hard to ID Synergy**
- **Missing Pieces**
- **Multiple answers to DM**
- **VV&C**
- **Abuser Friendly**

Federation:

To date this has been the most successful method for capturing the cause and effect relationships implicit in C4ISR on the battlefield. It allows fidelity where fidelity is needed and allows the analytical team to review the cause and effect relationships as they unfold at the seams of the individual models. These types of modeling efforts still fall prey to the same issues discussed above for Hierarchy of models.

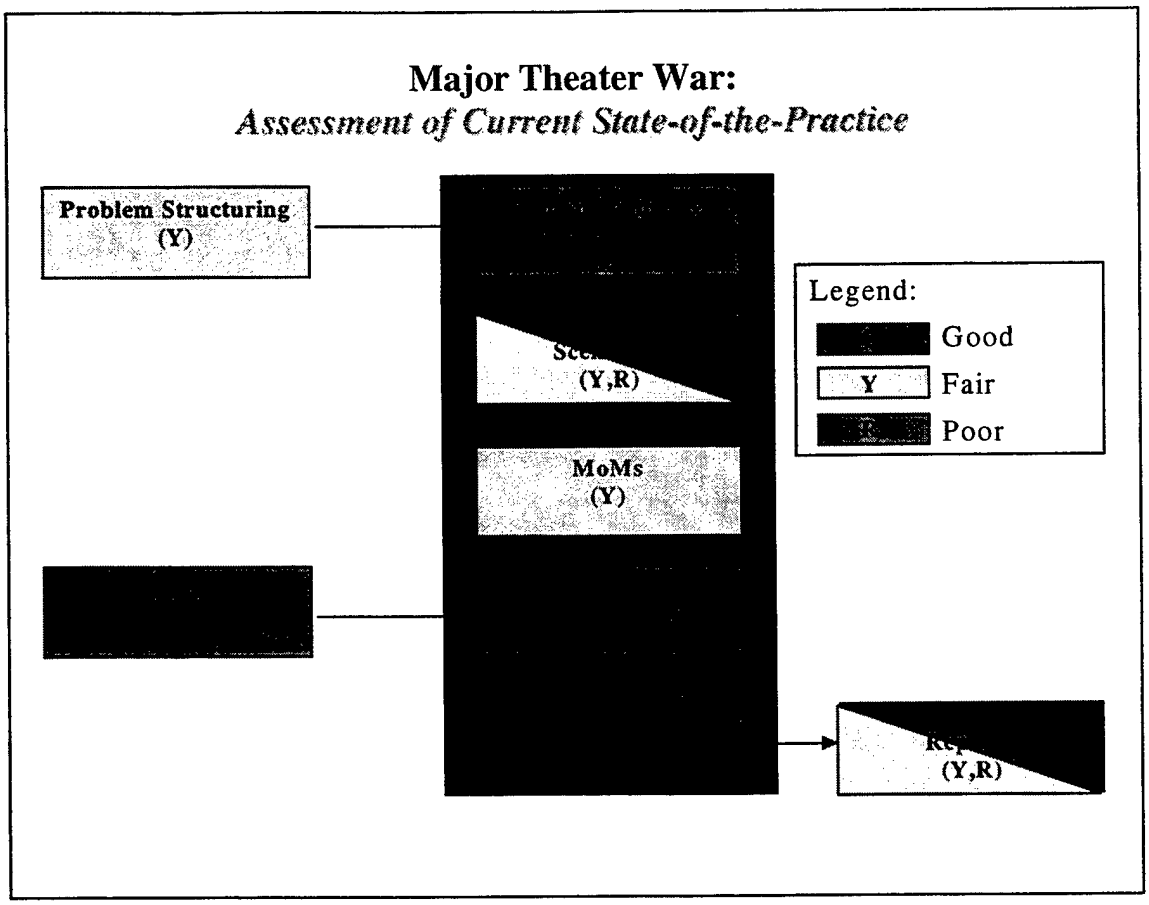
Major Theater War:
Methodology/Tools (Continued)

Non-Simulation Approaches:

- **Spread Sheets**
- **Analytic Model**
- **Man-in-The-Loop**
- **War games**
- **Exercises**
- **Historical Analysis**
- **Surveys/Operator Observations**

Non-Traditional Techniques:

A variety of non-simulation approaches may be used to answer parts of the analysis question (although it did not appear that any single technique was robust enough to approach answering all C4ISR-related questions in an MTW context). These techniques are listed on the slide, but should be considered to be a representative sample of the techniques available rather than a comprehensive list.



Assessment of the State-of-the-Practice: Using the same chart as used by other working groups:

Problem Structuring (Yellow):

- Strike issues *relatively* well understood, maneuver issues poorly understood
- Link between C4ISR MOEs and MOFEs not well understood
- System level performance issues & MOEs relatively well understood

Human Factors and Organization (Red)

- Behavior models not developed
- No Red behavior models, data, or dynamic scenarios available
- Data for behavior and decision making not available
- Human-in-the-Loop approaches are not repeatable and may not be verifiable
- Do we model doctrine, "real-world," normative or optimal decisions?
- Decisions tend to cause significantly nonmonotonic outcomes. They also tend to be nonlinear with respect to the stimulus (e.g., thresholds)

Assessment of the State-of-the-Practice (cont'd):

Scenarios (Red)

- DPG scenarios really don't get at C4ISR issues
- Conflict between a defined (scripted) scenario and showing C4ISR effects (which cause dynamic effects)

- Red behaviors (especially dynamics) not defined in scenarios or supporting data For ISR, DPG / MTW scenarios may not be the most stressful condition (DCI/peacetime may be largest/most stressing requirements)
- Issues that have great impact on C4ISR may not be significant in the scenario (e.g., SCUDs that launch against political vice military targets)
- Decisions & doctrine not defined in future scenarios

Measures of Merit (Yellow)

- C4ISR MOEs and MOFEs well understood but linkage between them is not
- MOMs very dependent on context – hard to make any general statements
- A good decision is not synonymous with a good outcome. This creates a problem when you use MOFEs as criteria for evaluation

Tools and their Applications (Red)

- No good models or tools exist for many C4ISR processes
- Red C4ISR not well understood or modeled
- Models under development (e.g., JWARS) are taking the "best current modeling approach" as their basis – since no good models exist currently, JWARS will not have any models to incorporate.
- Hierarchical and federated modeling approaches have significant problems with model consistency
- You can't model well what you don't understand

Data (Red)

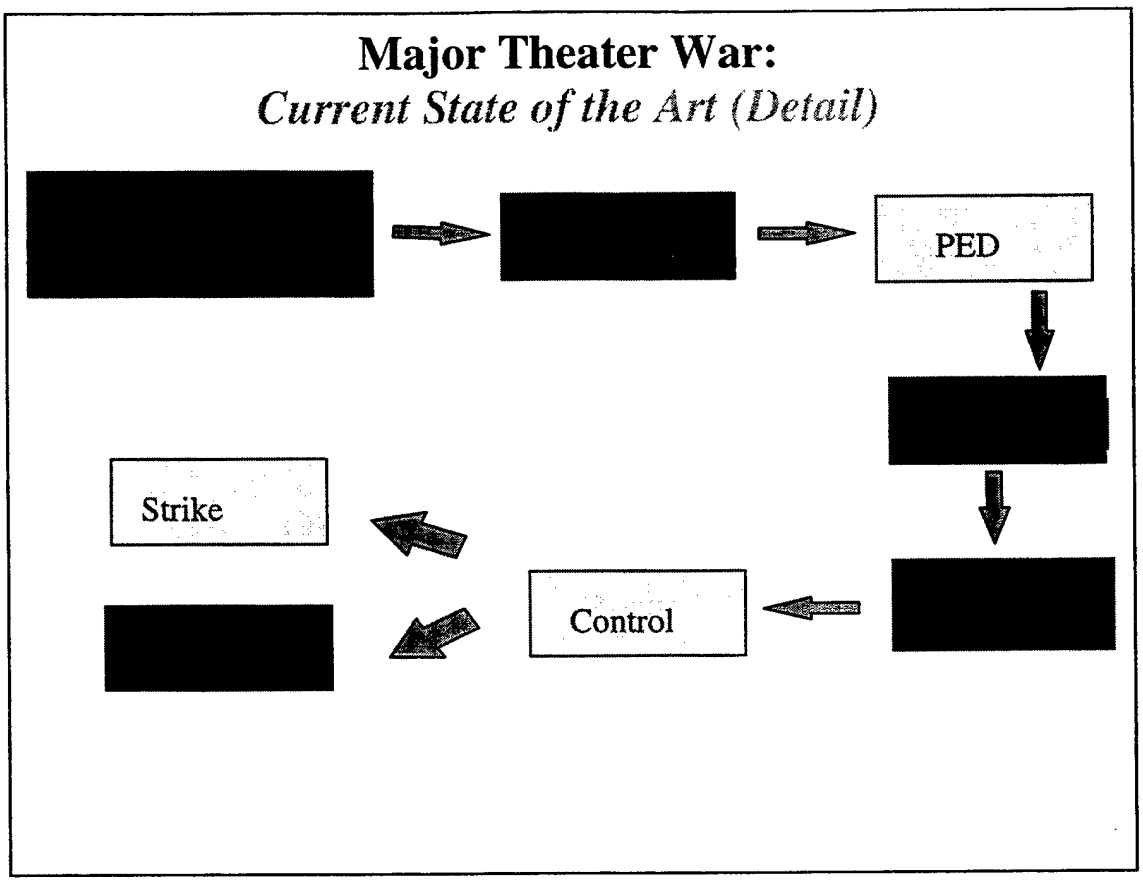
- Data generally does not exist on behavior and human issues
- Red C4ISR data particularly lacking (especially behavior)
- Doctrine is a form of data for C4ISR models — yet we don't have that well quantified, especially when future systems are included
- There is a big difference between physical attribute data and behavioral / decision data
- Funding is not there

Risk and Uncertainty

- Will the systems perform as expected? Relatively well understood
- Will the systems effect combat as modeled / hypothesized? Not understood
- Is the context correct? Not well defined for C4ISR — e.g., doctrine, future baseline, data, etc.
- Uncertainty is often modeled with probability— but we don't understand the models, much less the distributions, much less the distributional parameters

Report (Red)

- Because we lack C4ISR models and data are lacking, many assumptions have to be made. These assumptions (and their impact) may not be well reported to and understood by the DM
- Linkage assumptions between C4ISR and combat outcomes often not reported (may not even be understood by analyst if implicit in models)



Breakout of the state-of-the-art within the intelligence cycle:

These ratings were discussed previously; this slide simply summarizes the ratings.

Major Theater War:
Recommendations

- **Research needed to how we reflect C4ISR outcomes into military effects (e.g., maneuver)**
- **Research needed on perception development and fusion**
- **Research and data needed on decision making (C2) representation**
- **Funding needed for data collection and management. Cannot just be tied to existing models. (Will save analysis money in long run)**
- **We need to explain better to DM where model and analysis limitations are. Analysis demands seem to have shorter timelines and less money. "Quick turnaround" analysis may require extensive preparation (scenarios, data, etc.) be accomplished beforehand.**
- **New model development (e.g., JWARS) is based on "using the best of the accepted algorithms." Since C4ISR algorithms are missing now, the next generation of models will not have proper C4ISR representations.**

Major Theater War:
Recommendations (Cont'd)

- **Need to develop knowledge base for Red behavior (not just systems and general doctrine). Coalition behavior information also needed.**
- **JDS needs specific tasking to support C4ISR analysis beyond JWARS. This will require additional funding.**
- **Intel scenarios and combat scenarios need to be matched. Non-tactical intel requirements need to be defined in context of campaign.**
- **To ensure consistency across services, the QDR scenarios need to be fleshed out now by (or managed by) a single joint agency. This includes data and Red representation.**
- **More data sharing and sanitization of data (e.g., national systems) needed.**

Major Theater War:
The Bottom Line

- **Insight: Basic research is needed. Some major areas (not all inclusive):**
  - **Linkage between C4ISR effects and campaign outcomes,**
  - **Fusion, perception development and decision making,**
  - **Basic combat itself (e.g., maneuver effects).**
- **Insight: JWARS and other new model efforts are incorporating the "best" current models - this approach will not work with respect to C4ISR.**
- **Recommendation: Develop prioritized list in the areas of C4ISR effects on combat, C2, ISR, communications and basic combat to direct the research plan. Action: J-2, J-6, J-8, DSC (J-6 lead). Fund research, Action: DD(R&E) / ASD(C3I). This research needs to be implemented into new model developments, but we do not need the effort focused on a particular tool.**

Bottom Line" Recommendations:

The "Bottom Line" slides include the Working Group's recommendations regarding the appropriate implementing organizations. Those recommendations have not been formally coordinated with the organizations listed.

Major Theater War:
The Bottom Line (Cont'd)

- **Insight: There are fundamental data gaps to support C4ISR.**
- **Recommendation:**
  - **Enumerate the data requirements (more than JWARS support), Action: ASD(C3I)/DSC/Joint Staff/IC**
  - **Populate the data bases, Action: ASD(C3I) DSC/JDS/DD(R&E) DMSO**
  - **Make available to community. Action: JDS**

- **Insight: C4ISR analysis will require a range of different models, which may include but will not be limited to JWARS.**
- **Recommendation: Develop a requirement and funding plan to develop the analysis infrastructure (data, tools, etc) needed to respond to current demands. This is more than JWARS and JDS. This needs to be in place by the QDR. Action: J-2, J-6, J-8, DSC (J-6 lead).**

Analyzing C4ISR for 2010

Smaller Scale Contingencies

Smaller Scale Contingencies (SSC) proved difficult to define well and difficult to differentiate from Operations Other Than War (OOTW). The group chose to focus its efforts on mission types in which the use of military force was likely (raids, hostage rescue, opposed NEOS, etc.), which were also discussed as those for which military considerations tend to take precedence over political considerations. This distinction was adopted in order to focus the Working Group on a different arena from the OOTW group, which focused most of its energy on Peace Operations and Humanitarian Assistance and Disaster Relief missions.

The group recognized that this is an artificial distinction. Many formal definitions of OOTW explicitly include SSC. Moreover, SSC intended as nearly pure military operations often are changed into more political activities. The scenario played out in Haiti (which went in a matter of a few minutes from an invasion of a small country to a friendly occupation with primarily political goals) provided a good example of this phenomenon. Finally, as the group stressed in its deliberations, SSC tend to have significant political dimensions, even when the operations themselves are largely military in character.

The Working Group also concluded that analysis of SSC cannot be meaningfully conducted on the group of missions as a whole. Their diversity requires that tools and analytic efforts be focused on meaningful, coherent subsets of the topic. For example, studies of raids will require different tools and data than studies of hostage rescues.

Smaller Scale Contingencies:
Participants List

NAME	ORGANIZATION
Anway-Wiese, Carol	Boeing
Cann, David	Naval Undersea Warfare Center, Newport
Chartier, Chris	OASD (C3I)/Decision Support Center
Cherolis, George	TRW Tech Support for TACCSF
Coe, Gary	IDA
Elton, Olaf	MITRE
Forsythe, Steven L. (Major USAF)	AFSAA/SAAB
Hayes, Richard E. (Chair)	Evidence Based Research Inc.
Herlihy, Anthony R. (Major, USMC)	Marine Security Guard Bn.
Kirkland, Joseph K.	Evidence Based Research Inc.
Macklin, Marilyn	HQ, Dept. of the Army
McGregor, Otis (Captain, USA)	US Army LIWA
Morrell, Angela	US Special Operations Command SOIO-C4I
Oswalt, Ivar	Kapos Associates Inc./N6M Support
Peterson, Pat	SAIC
Richards, Dale	USAF Research Laboratory/IFTB
Siegel, Adam	Center for Naval Analyses (CNA)
Wheatley, Gary (RADM USN Ret.)	Evidence Based Research Inc.

Who Participated:

The eighteen individuals who participated are listed on the slide. They represented an excellent mix of C4ISR analysts and operators with widely divergent backgrounds and training. While this diversity made communication difficult at times, the members of the Working Group did an excellent job of working with one another. No one perspective dominated and a remarkably coherent and consistent perspective emerged over time.

Smaller Scale Contingencies:
Characterize C4ISR

- **Require more rapid & agile:**
  - **Intelligence processes**
  - **Continuous/dynamic planning & execution**
- **Pressure toward centralized control**
  - **"Only game in town"**
  - **Strategic implications of tactical activity**
- **Danger of different understandings of the situation across command echelons**

Characterize C4ISR (1):

While the Working Group was cognizant of the need to differentiate SSC from other types of operations, many of the ways that C4ISR needs are characterized in this arena would be the same as those in other arenas. For example, looking at future SSC, the dominant requirement will be for more rapid and agile intelligence, planning and execution processes. While not unique to SSC, this need will be important and analysts must be looking for ways to ensure it is met. This means exploring ways to improve the speed and responsiveness of the entire ISR process (from tasking through dissemination) as well as to couple situation awareness, decision making, and execution more closely.

SSC are different from MTW, at least, in that they almost always involve considerable pressure for centralized control. This arises both from the legitimate concerns of higher command arising from the potentially strategic implications of military activities down to the
tactical level and the more idiosyncratic fact that SSC are often "the only game in town," which means that decision makers at all levels are free to invest time in them. MTW, on the other hand, are often large and complex enough that senior political and military officials often are to busy to focus on tactical level decisions and actions.

Given the high level of attention likely to be generated, the danger also arises of different understandings of the military and political situations at different levels of command. These disconnects can threaten the coherence and ultimate success of the operation.

SSC may (but do not always) also require a high level of tactical security (particularly in the planning, preparation and entry phases) and management of highly visible consequences. The experience of conducting an operation that is a military success yet fails in terms of US policy was all too familiar to the Working Group participants.

Communication issues arose several times during the discussion. SSC often require new or novel infrastructures that overcome gaps arising from military service differences, the need to include coalition partners or host nations, or the need to deal with non-military actors (inter-agency or NGO). Moreover, secure communications may be needed to achieve adequate operational security.

Smaller Scale Contingencies:
Characterize C4ISR (cont'd)

- **May Require:**
  - **High level of tactical security**
  - **Management of highly visible consequences**
  - **Specialized communication capabilities:**
    - **Infrastructure**
    - **Security**
    - **Coalition**

Smaller Scale Contingencies:
Key Issues and Questions

- **SSC not necessarily a lesser included case of MTW**
  - **MOFE and MOPE not "controlled" by the military**
  - **Intelligence required tend to be more fine grained and detailed than for MTW**
- **Definition of mission success/failure often includes constraints not present in MTW.**
- **Tension between:**
  - **Avoiding mission failure**
  - **Maximizing likelihood of mission success**

Key Issues and Questions:

The Working Group wanted to emphasize that SSC are not necessarily a lesser-included case of MTW. This is crucial when data is being selected, models chosen, parameters estimated, or research is being organized. Some of the distinctions were mentioned earlier. Others include the fact that the MOFE and MOPE are usually not under the control of the military. In this sense, SSC are properly understood to be OOTW. Moreover, the group, and particularly the operators in the group, stressed the fact that the intelligence required in many SSC is more fine grained and detailed than that required for the same levels of command in MTW.

SSC are often conducted under restraints that would not be present in MTW. Rules of Engagement (ROE) and political restrictions often limit the activities available for mission accomplishment. Moreover, SSC tend to be characterized by a very meaningful tension between efforts to avoid mission failure and maximizing the likelihood of mission success. Examples of decisions to limit the size and armament involved in operations in order to avoid undesirable political consequences were offered by several members of the Working Group.

Smaller Scale Contingencies:
Relative Worth

- **Improved C4ISR in SSC should yield benefits such as:**
  - **Economy of force**
  - **Agility and synchronization**
  - **Improved operational performance**
  - **Improved policy effectiveness**
  - **Improved mission accomplishment**

Relative Worth:

The group noted that improved C4ISR should pay off in some very specific ways in SSC. In particular, greater agility in situation awareness, planning and execution were placed paramount in importance. Not only better operational performance, but also improved likelihood of mission accomplishment and policy effectiveness were considered possible. Additional benefits should include improved agility and synchronization and greater economy of force.

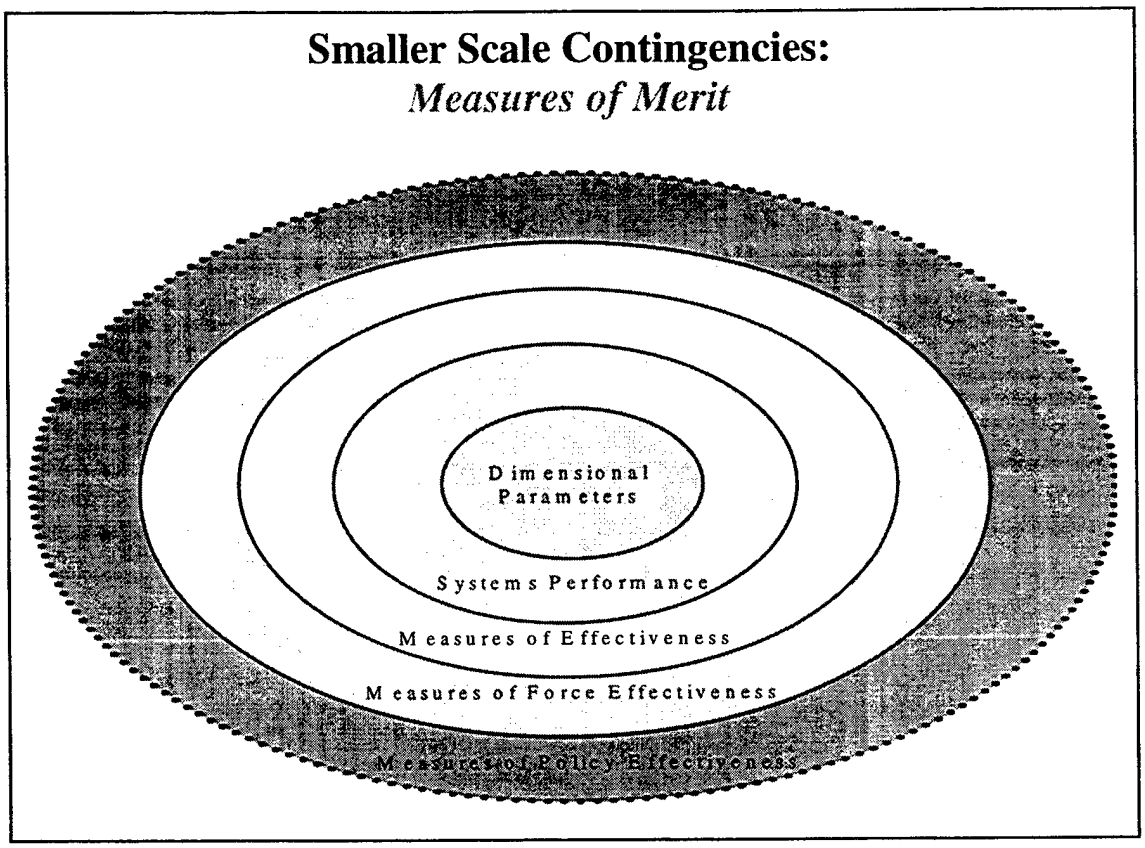
Smaller Scale Contingencies:
Assessing Relative Worth

- **Assessment of the relative worth of C4ISR systems requires considering:**
  - **Range of SSC missions and their relative likelihood**
  - **Impact on MOFE**
- **Tools and methods for assessing relative worth require substantial verification, validation, and accreditation (VV&A)**

Assessing Relative Worth:

The method for assessing the relative worth of C4ISR systems was seen as readily available from fundamental operations research techniques. This is not to say that the data and tools needed to conduct those analyses are available. Simply stated the group recognized the value of a particular C4ISR innovation could be seen as a function of the range of SSC missions to which it applies, the relative likelihood of those mission types and their estimated impact on the relevant MOFE and MOPE. After explicit discussion, the group rejected the idea that the "importance" of the mission type be added to the equation, arguing that any one type of mission might be crucial to US national interests under selected circumstances. The obvious example of this is the crucial role of the blockade during the Cuban Missile Crisis.

The working group also felt compelled to point out the need for verification, validation and accreditation (VV&A) for tools, methods, and data being used to conduct these relative worth analyses.



Measures of Merit (1 and 2):

The group readily accepted both the set of measures of merit categories defined by MORS in the 1980s and the suggested change offered by Dr. Stuart Starr during his plenary address, of adding an outside layer, Measures of Policy Effectiveness (MOPE). Equally important, the group also wanted to ensure that analyses of C4ISR in SSC "be informed by" metrics from all the relevant layers. The conclusion was not that all analyses include all levels of measurement. For example, many analyses are focused on existing equipment for which the dimensional parameters are fixed. However, the Working Group wanted to emphasize the need for analysts to be aware of the limits of analyses that do not consider all the levels.

Smaller Scale Contingencies:
Measures of Merit (cont'd)

- **Analysis of future C4ISR systems should be informed by measures of merit at all the MORS-defined levels**
- **Interoperability**
- **Distribution of information:**
  - **Include military, interagency, and coalition partners**
  - **Appropriate balance of push/pull**

Measures of Merit (1 and 2, cont'd):

Interoperability issues also arose several times. Despite the emphasis on this topic since Grenada, it continues to bedevil operators in SSC. This also confounds (but is not the only confounding factor) the distribution of information. Despite changes in policy arising from the Bosnia experience, the people on the spot who do the planning and support the execution of SSC are often unaware of, or are unable to acquire ISR products in a timely manner. This problem arises across service, national and functional lines. The correct balance of information push and information pull has not yet been achieved. Metrics for interoperability and for information dissemination remains important in assessing future C4ISR systems.

Smaller Scale Contingencies:
Measures of Merit (cont'd)

- **Quality of information is the key dimension**
  - **Responsive to war fighters**
    - **Cover CCIR**
    - **In useable format**

  - **Characterized as:**
    - **Complete**
    - **Current**
    - **Correct**
    - **Precise enough for purposes**
    - **Consistent: internally and across command centers**

Measures of Merit (3):

The quality of the information available was seen as the single most important metric for SSC. This was defined to include its responsiveness to warfighters, including the Commander's Critical Information Requirements (CCIR), but also the needs of key staff members and the units executing the operation. Responsiveness was seen as including much more than mere availability. Some operators reported "drinking from a fire hose" when they were given "all the relevant" material. Others noted that they often received material in a format that either was not readable or was difficult to use. Here, again, the proper balance of push and pull is crucial.

What is meant by high quality information was based on the Headquarters Effectiveness Assessment Tool, which was familiar to several members of the Working Group. "Perfect" information in a military situation is seen as complete (for the command's needs), current, correct, precise enough for the associated military purposes (which will vary from targeting, which is very precise, to general maneuver planning, which is often much less precise) and consistent. Consistent here means both internally consistent within the data, information, and knowledge of the C4ISR system and consistent across command nodes.

Smaller Scale Contingencies:
Measures of Merit (cont'd)

- **Anticipation of Key Demands for:**
  - **Intelligence**
  - **Logistics**
  - **Operations**
  - **Communications**

- **Rapid and robust situation assessment, decision making, planning, execution:**
  - **Speed**
  - **Variety of alternatives**
  - **Quality (effectiveness)**

Measures of Merit (4):

The group also wanted to stress the need for future C4ISR systems that will be anticipatory across the full range of key demands that arise in command and control: operational, intelligence, logistics and communications. In other words, if continuous and effective planning and execution systems are to work, the system must be thoroughly cross-linked in very near real time.

Similarly, measures of merit that focus on rapid and robust decision making, planning and execution will be needed. This means we need valid and reliable indicators of the speed of the C4ISR processes, the variety of futures and alternative courses of action they can and do consider, and the quality of the decisions they make. Indicators of decision quality essentially must be MOFE and MOPE, though MOE for C4ISR, MOP for C4ISR systems and the dimensional parameters that drive them may also be needed for diagnostic purposes in any given analysis.

Smaller Scale Contingencies:
Tools Needed

- **Improved support tools for COA**
  - **Credible projections of alternative futures**
  - **Capacity for "what if?" analysis**
  - **Fast enough to support mission planning**
  - **Must be able to pull from current operational databases**
- **Virtual C4ISR rehearsal capability**
  - **Analytic tool**
  - **Operational tool**

Tools Needed (1):

This area was perhaps the least mature of the areas discussed in the working group. Tension existed between the desire to identify tools for C4ISR analysts and tools needed by the operators. The requirements were seen to be quite similar in many cases and the group identified several tools that would be of value to both.

The most important tool requirement was for credible support to course of action (COA) analysis. This means tools that generate projections of alternative futures that are credible to operators and well as the capacity for sensitivity or "what if" analyses. These tools must also be fast enough to support mission planning and have an analytic mode that permits large numbers of runs in a short period of time. Moreover, these tools must be designed to pull from operational databases, not just notional or analytic ones.

Perhaps the most novel idea arising for new tools was a call for a virtual C4ISR rehearsal capability that would be designed both as a tool for analysts and for operators. Operators would use it for training and mission rehearsal. Analysts could use it for improving their understanding of missions, generating hypotheses about C4ISR improvements, examining man in the loop elements, and testing hypotheses.

Smaller Scale Contingencies:
Tools Needed (cont'd)

- **Improve data collection and control**
- **Identify and link simulated and real data**
- **Future systems better integrated across:**
  - **Functions**
  - **Echelons of Command**
  - **Time**
  - **Capability to model/ameliorate the impact of language, culture and training differences**

Tools Needed (2):

The group heard a similar plea for more effective ways to both link and differentiate real and simulated data, particularly in real headquarters participating in virtual exercises and training.

In general, tools are needed to assess the degree to which C4ISR systems are linked across functions, echelons and time. New information systems are linking operators more and more closely, but no tools to measure these changes or their impacts are currently available. Similarly, models that capture the effects of "soft factors" such as differences in language, culture, or training are not available but would be valuable in an era that stresses "jointness" and coalition operations.

Smaller Scale Contingencies:
Tools Needed (cont'd)

- **Virtual C4ISR rehearsal capability**
  - **Analytic tool**
  - **Operational tool**
- **Simulation for rapid integration and deconfliction of communications**
- **Rich relational databases with improved linkage software**
- **Uncertainty estimator and communicator**
- **Ability to capture and replay data/voice/imagery traffic for current and future operations**

Tools Needed (3):

The number and variety of communications "horror stories" called out by both the plenary speakers and the operators in the Working Group were seen as indicating a need for a simulation that would focus on the capability to rapidly integrate and deconflict the "kluges" of systems often required in SSC.

Rich relational databases, focused on the SSC mission areas were also seen as important, as was development of improved linkage software to speed searches and enhance their utility. Finally, systems that can estimate and communicate uncertainty in the context of C4ISR systems and the information they present were also seen as important.

Analysts, particularly those supporting operational organizations, also felt a need to capture and replay information (data, voice traffic, imagery, etc.) for current and future operations. This would greatly facilitate after action analyses from both operations and exercises.

Smaller Scale Contingencies:
Examining Illustrative C4ISR Smaller Scale Contingencies

Mission Types	*Future of C4ISR*	*Analytic Tools*	*Measures of Merit*	*Key Metrics*
Raid	➢ *3D Imagery*	➢ *Predictive Modeling*	➢ *MOFE> MOPE*	➢ *Mission Accomplishment*
		➢ *Virtual Rehearsal*	➢ *MOP*	➢ *Collateral Damage*
				➢ *Interoperability*
				➢ *Speed*
				➢ *Targets Destroyed*
				➢ *Minimum US Casualties*

Illustrative Examples (1) – Raid:

Slides 15 through 18 represent detailed work performed by the working group, which actually examined four different types of SSC mission areas to link future C4ISR needs, the analytical tools required to support their development and refinement, the most crucial measures of merit, and the implied key metrics.

In the Raid analysis the group determined that the critical C4ISR product is timely 3D Imagery. This imagery is essential to support the needed analytic tools of Predictive Modeling and Virtual Rehearsal, which were in turn believed to offer potential for greatly improved mission success. Measures of merit are dominated by MOFE and MOPE, with Force Effectiveness deemed somewhat more important the Measure of Policy Effectiveness. Key Metrics include Minimum US Casualties, Minimum Collateral Damage, Interoperability of C3I and number of Targets Destroyed in the raid.

Smaller Scale Contingencies:
Examining Illustrative C4ISR Smaller Scale Contingencies (cont'd)

Mission Types	*Future of C4ISR*	*Analytic Tools*	*Measures of Merit*	*Key Metrics*
Urban Warfare	➢ *Global Positioning System*	➢ *Predictive Modeling*	➢ *Inter-operability*	➢ *Minimum US Casualties*
	➢ *Databases as Intel Products*	➢ *Virtual Rehearsal*	➢ *Economy of Force/Cost Effective-ness*	➢ *Collateral Damage*
	➢ *Communications Continuity*	➢ *Maneuver Models*	➢ *Maneuver-ability*	➢ *Interoperability of communi-cation and computers*
	➢ *Identification Friend or Foe for land forces*	➢ *Intel/Ops Automation*		➢ *"Key Nodes to Take" in urban terrain*
	➢ *Language Translators*	➢ *Communi-cations simulation*		

Illustrative Examples(2) -- Urban Warfare:

Urban Warfare offers perhaps the biggest C4ISR challenges today and in the future. These include enhanced utilization and exploitation of GPS for precise three dimensional positioning, Combat Identification of friend and foe in densely populated areas where non-combatants are often mixed with the enemy, and communications that will function seamlessly from sewers to skyscrapers. Detailed databases are essential to support Predictive Modeling and Virtual Rehearsal tools. Measures of Merit stress Interoperability and Economy of Force with key metrics similar to those in the previous example.

Smaller Scale Contingencies:
Examining Illustrative C4ISR Smaller Scale Contingencies (cont'd)

Mission Types	*Future of C4ISR*	*Analytic Tools*	*Measures of Merit*	*Key Metrics*
Counter-terrorism/ Operational Disruption	➢ *Relational databases with linkage software* ➢ *Better organized data* ➢ *Threshold control*	➢ *High volume of data* ➢ *Knowledge-able domain experts* ➢ *Prioriti-zation "tags" for intelligence alerts*	➢ *Hits verses false alarms* ➢ *Level of confidence* ➢ *Level of uncertainty*	➢ *Decrease in terrorist attacks* ➢ *Increase in terrorist threat*

Illustrative Examples(3) -- Counter Terrorism/Operational Disruption:

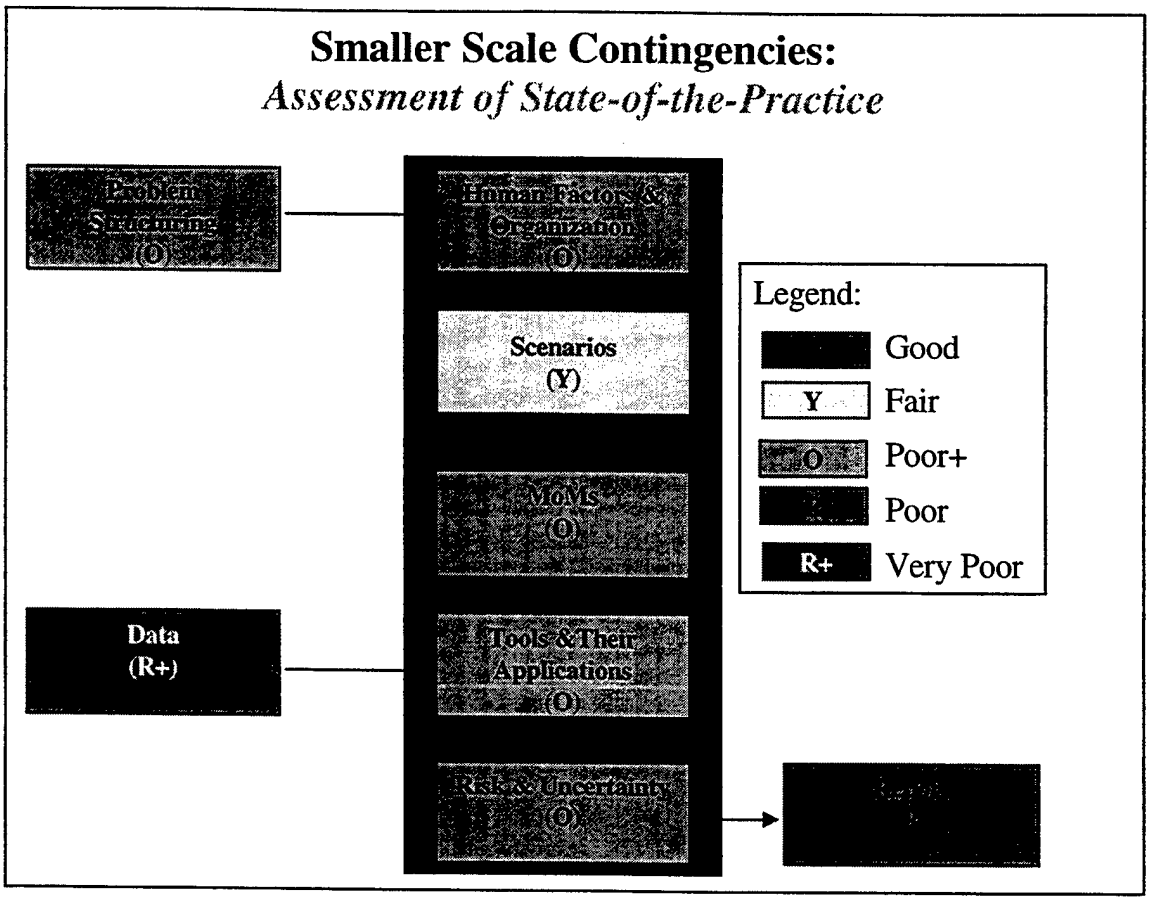
Terrorism and other trans-national threats are quickly becoming epidemic. As developed in previous counter-narcotics analyses, terrorists, drug czars and similar actors can be identified and located through concentrated research and analysis. The key is the data, and future C4ISR to address these threats will require much better organized data that can be linked through relational databases. Analytic tools can then use the data to identify and locate terrorists. Measures of Merit will address the success of the analyses and focus on accuracy of hits versus false alarms, and the confidence level of the alerts.

Smaller Scale Contingencies:
Examining Illustrative C4ISR Smaller Scale Contingencies (cont'd)

Mission Types	*Future of C4ISR*	*Analytic Tools*	*Measures of Merit*	*Key Metrics*
Opposed NEO/ Potentially Opposed NEO	➢ *Information on terrain* ➢ *Improved interagency / coalition C4ISR* ➢ *Ability to monitor situation and operative environment* ➢ *Detailed Intel products*	➢ *Modeling & Simulation Anticipatory* ➢ *COA Analysis Tool*	➢ *MOFE< MOPE* ➢ *Quality of information* ➢ *MOP*	➢ *Mission Accomplish-ment* ➢ *Minimum US and civilian casualties* ➢ *Increase in capability of number of people evacuated*

Illustrative Examples(4) -- Opposed/Potentially Opposed NEO:

An Opposed or Potentially Opposed NEO is perhaps one of the most difficult and delicate missions which our armed forces are called upon to conduct. These missions literally mean life or death to US and other friendly civilians, and create high visibility political consequences. Key C4ISR capabilities needed are detailed and current intelligence products to include precise terrain and building data, and continuous or near continuous location information about evacuees and potential opponents. M&S tools that provide rehearsal capability and COA analyses are particularly needed. In this mission MOPE and MOFE are paramount with MOPE most important. Mission accomplishment with minimum US and civilian casualties are the Key Metrics.



Assessment:

This slide is self-explanatory except that the Working Group felt that many areas fell between red and yellow and chose to color them orange.

Smaller Scale Contingencies:
Recommendations

- **Develop clearer definitions to support analysis**
- **Focus on specific missions rather than artificial categories**
- **Baselines are essential for good analyses and must be developed for the mission types included in SSC**
- **Invest in the C4ISR analysis tools identified by the working group (e.g., VV&A)**

Recommendations (1):

The recommendations were difficult to draft and represent only a fraction of the rich discussion and debate of the working group. Those recommendations ranged from:

- the difficulty of defining SSC (ultimately resolved in the very practical way of noting that the included mission types are really the focus of analysis)
- the argument that baselines do not exist for most of these mission types
- meaningful analysis must have those crucial baselines for assessment of the contribution of current and future C4ISR systems.

The most fundamental recommendation was that DoD and the MORS community begin an investment program in the tools identified as necessary.

Smaller Scale Contingencies: *Recommendations (cont'd)*

- **Further research to develop methods for collection and analysis of the importance of measures of policy effectiveness (MOPE) for SSC**
- **Invest in better storage and distribution databases of relevant C4ISR information for each SSC mission area**
- **C4ISR must be interoperable, including interagency and coalition players**

Recommendations (2):

The area of MOPEs was also called out as an area crucial to further progress in SSC. This finding was expected to be similar to one reported by the OOTW Working Group. Investment in databases (and information and knowledge bases) to support SSC mission area analyses was also identified as a very important recommendation.

Smaller Scale Contingencies:
Summary

- **Future and current needs of C4ISR within SSC must be mission focused**
- **SSC require more detailed, "fine grained" data from C4ISR elements**
- **Investment in relevant C4ISR information and C4ISR COA tools recommended**
- **Development of baselines, information and further research necessary**

Summary:

The current and future C4ISR needs for Smaller Scale Contingencies must be addressed within the context of each specific mission category, as opposed to addressing a broad range of similar missions. By heeding this, proper analysis of each mission area may be secured. C4ISR data within Smaller Scale Contingencies will need to develop a higher level of tactical detail and control then other arenas of warfare (i.e. peacekeeping, peace enforcement, major theater war.) This characteristic, developed from tight operational constraints, will aid commanders' tactical planning, control and security. Investment in such C4ISR information systems such as virtual rehearsal programs, course of action analytical tools and relational databases is recommended to increase military force flexibility and performance.

Analyzing C4ISR for 2010

Operations Other Than War

Operations Other Than War:
Working Group Taskings

- **Characterize C4ISR within WG focus area**
  - **Decompose the elements of C4ISR**
- **Define the relative worth of C4ISR**
  - **C4ISR/Firepower/Force Employment**
- **Develop & Recommend Measures of Merit**
  - **MOPs and MOEs**
  - **How well they value C4ISR, estimate ROI**
- **Identify and describe tools**
- **Analyze, synthesize, and infer**

Working Group Tasking:

The Terms of Reference charged the Working Group to undertake five tasks:

1. Across the range of OOTW missions, decompose the aspects of C4ISR and consider the analysis issues associated with them. The objective is to consider the value of CISR contributions.
2. Continue the assessment by considering the relative worth of C4ISR to "firepower" and force employment. Note here that "firepower" is a misnomer for force capabilities and systems, since generally the missions and tasks of OOTW will require other than the prime warfare systems.
3. Considering the types of analysis to be performed, develop measures of merit (MOPs and MOEs) that are appropriate to the mission areas. Also, address the ability to conduct assessments of return on investment.
4. Identify tools and methods that are necessary to the analysis described above.
5. Finally, consider all the information generated to draw conclusions and observations.

Operations Other Than War:
Group Participants

• **Art Dougas**	**Booz-Allen**
• **John Furman**	**Mitre**
• **Bob Hartling**	**OPNAV 81**
• **John Kelsey**	**TASC**
• **Randall (Mel) Parish**	**TRAC-WSMR**
• **Terry Prosser**	**Logicon**
• **Mark Sinclair**	**Joint C4ISR Battle Center (Veridian)**
• **Mike Sovereign**	**Naval Postgraduate School**
• **Cy Staniec**	**Logicon**
• **Don Theune**	**Virtual Technology Corporation**
• **Corinne Wallshein**	**AFSAA/SAAB**
• **Scott Welch**	**Evidence Based Research**
• **Russ Richards**	**Mitre (Synthesis Group)**

OOTW Group Participants:

Dr Cy Staniec chaired the group, with John Furman and Terry Prosser as co-chairs. The group included a broad array of skills and experiences, including recent experience in PACOM activities (Prof Mike Sovereign and Mark Sinclair) and Bosnia (Terry Prosser). Dr Russ Richards participated as a member of the Synthesis Working Group.

Operations Other Than War:
Background

- **1996- PACOM Workshops**
- **January 1997 - MORS OOTW Workshop**
- **October 1997 - HA/DR IN THE NEXT CENTURY**
  - **CCRP report**
  - **VIC Concept description**
- **April 1998 briefing "Peacekeeping in Bosnia- New Frameworks for Analysis"**

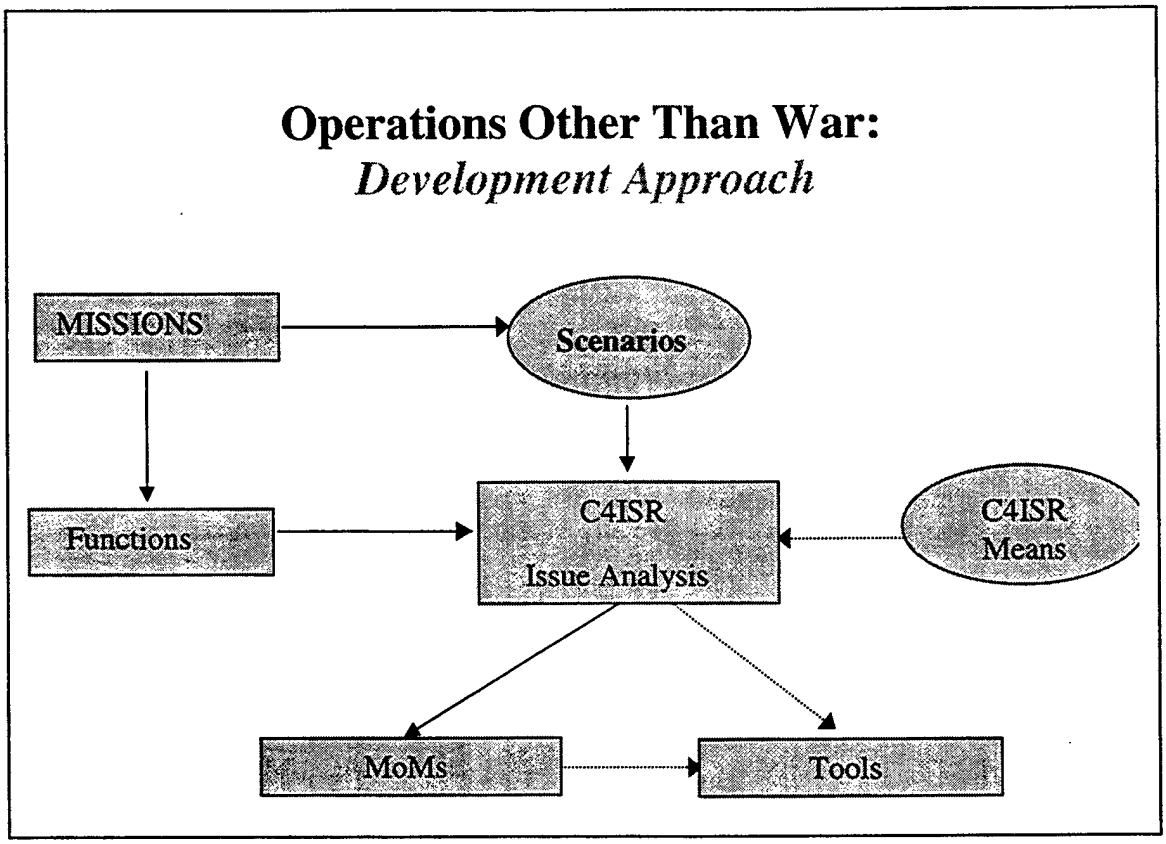
Background:

Previous workshops and activities provided groundwork for this working group. Several of the participants had been involved in the PACOM-sponsored workshops addressing OOTW analysis held in 1996. In January 1997, MORS also conducted a workshop on analysis methods and tools for OOTW. The C4ISR group characterized the complexities posed by the OOTW missions, and cited some of the differing analysis requirements and the need for tools to support analysis.

Further background work was provided via a report entitled Humanitarian Assistance and Disaster Relief in the Next Century. (DoD C4ISR Cooperative Research Program, October 28-30 1997). This report, written by Professor Mike Sovereign, documented working groups focused in three main areas: collaboration, cooperation, and coordination (C3) for HA/DR; information acquisition for HA/DR; and crisis management in HA/DR operations. Mark Sinclair gave an overview of the Virtual Information Center concept conceived in the workshop and demonstrated in PACOM. The VIC concept proved valuable to support crisis planning and allowed innovative analysis and problem solving in these missions.

Finally, Terry Prosser presented a briefing entitled "Peacekeeping in Bosnia – New Frameworks for Analysis" that reflected the issues and measures he was faced with while serving as analyst on the Bosnia task force in 1997.

These inputs provided a focused starting point for the efforts of this working group.



Development Approach:

In order to address its assigned tasks, the group worked through a decomposition process depicted on this slide. For the set of OOTW missions, we first derived a set of typical functions within the missions and identified typical mission scenarios for analysis. For the scenarios, we considered how C4ISR means were employed in the mission. By crossing the C4ISR means with the mission functions, we were able to identify the most interesting C4ISR evaluation issues. Finally, these led to a categorization of typical measures of merit and the appropriate tools to assess them. The results of the process are presented in the following slides.

Operations Other Than War:
Functional Characteristics of OOTW

	PK	PE	PB	HA/DR	CS	NA	CD	CI
Security Opns	X	X	X		X			X
Police Opns		X	X		X	X	X	X
Refugee Opns	X			X	X	X		
Resettlement	X		X		X	X		
Compliance	X	X					X	
Inspection		X					X	
Surveillance	X	X	X	X	X	X	X	
PSYOPS (Perception)	X	X	X					
Civil Affairs			X	X	X	X		
Sustenance			X	X	X	X		
Medical Opns		X		X	X	X		
Governance	X	X	X	X				

Key:

PK: Peacekeeping
PE: Peace Enforcement
PB: (Peace Building)
HA/DR Humanitarian Assistance/Disaster Relief
CS: Civil Support
NA: Nation Assistance
CD: Counter-drug
CI: Counterinsurgency (support)

Mission/Functional Characteristic Matrix:

The decomposition step identified the twelve major functions associated with OOTW missions. The missions considered were peace keeping, peace enforcement and peace building (PK/PE/PB), humanitarian assistance and disaster relief (HA/DR), civil support, nation assistance, counter drug and counterinsurgency. By agreement, any other mission in which combat might be anticipated was left to the Small Scale Contingency working group.

From this decomposition, it is easy to assess where C4ISR means may be significant to mission accomplishment for each mission. Because of the limited time to the workshop and the particular expertise of the group, we focused on the PK/PE/PB and HA/DR mission areas.

Operations Other Than War:
OOTW Mission Characteristics

- **Characteristics of PK/PE**
  - **Focus Different :**
    - **Prevent conflict**
    - **Restore governance**
    - **Stabilize Situation**
    - **Exit**
  - **Multiple participants**
  - **Operations last beyond US Military participation**
  - **Security operations are Primary**
  - **Level of force varies**
- **Characteristics of HA/DR**
  - **Focus Different:**
    - **Stop the dying**
  - **Variety of participants (players)**
  - **Operations last beyond US Military participation**
  - **Small footprint**
  - **Definition of winning is different ("hearts and minds")**

Different Missions - Different Issues: Similar Problems to Address

OOTW Mission Characteristics:

In order to get to the measures of merit necessary for analysis, two subgroups were formed. One group considered the Humanitarian Assistance/Disaster Relief mission area and the other considered Peacekeeping and Peace Enforcement. In each case, the subgroup listed some of the mission objectives and characteristics that would drive analysis objectives.

In each case, it was clear that the main mission objectives were quite different than the mission objectives of mid-intensity warfare. In the case of PK/PE, mission objectives focus on security operations, prevention of conflict, and rebuilding of governance and economic stability. On the other hand, the focus of HA/DR is on emergency support, including objectives like "stop the dying."

In both cases, missions involve multiple participants, usually beyond the US military. In many cases, a small footprint in desirable, though expeditious completion of the mission is also desired. And the forces necessary for mission completion will be tailored mix. In the case of PK/PE, combat and combat support forces capable of preventing combat and providing security are important. In HA/DR, engineers, medical support are appropriate.

These observations mean that the measures used in analyzing and assessing these missions will both differ greatly across the missions and will also differ greatly from the type of measures used in theater warfare. This will be demonstrated in greater detail in the next slides. As might be expected, analysis of C4ISR within these missions will pose a variety of challenges substantially different than those faced in theater warfare.

Operations Other Than War:
Example Decomposition - PE/PK

CLASS	MOE	DATA	SOURCES	SYSTEMS
Mission Accom-plishment	Freedom of Movement	Define boundaries, # crossings	Observations & Cameras	HUMINT SIGINT Civil Affairs Public Affairs PSYOPS IMINT Maneuver Military Police Signal Corps INTEL Weather personnel Air Traffic Control Medical
	Police H/R violations	Define & Count	Media & Reports	
	Compliance violations	Define & Count	Inspections & Reports	
	Polling results	Conduct polls, collate	PSYOPS & Public Affairs	
	Government Sovereignty	Define, Count & Monitor	IO & Reports	
	Media trends	Collect, review, & collate	Civil Affairs & Public Affairs	
	Economic trends	Market Analysis	International Organizations & Counters	
	Health trends	Disease Rates	IO & indigenous reports	
	Freedom of Action			
	Cost			
	Time to complete			
Force Protection	Threatcon	Monitor	Intel / Sensors / Reports	
	Casualty trends	Monitor / Report	Forces / Reachback	
	Terrorist Incidents	Monitor / Report	Forces / Intel	
	Credibility	Monitor / Report	Forces / Intel	

Example Decomposition -- PK/PE:

These two slides show decomposition for the PK/PE mission area. This particular decomposition is based on experience with the Bosnian situation, but it is worth noting that the particular result would change for different situation.

General areas of interest are in mission completion measures, force protection measures, decision making measures, and interoperability measures. Within these areas, the decomposition addresses measures that are appropriate for C4ISR tradeoffs.

Operations Other Than War:
Example Decomposition (cont'd) - PE/PK

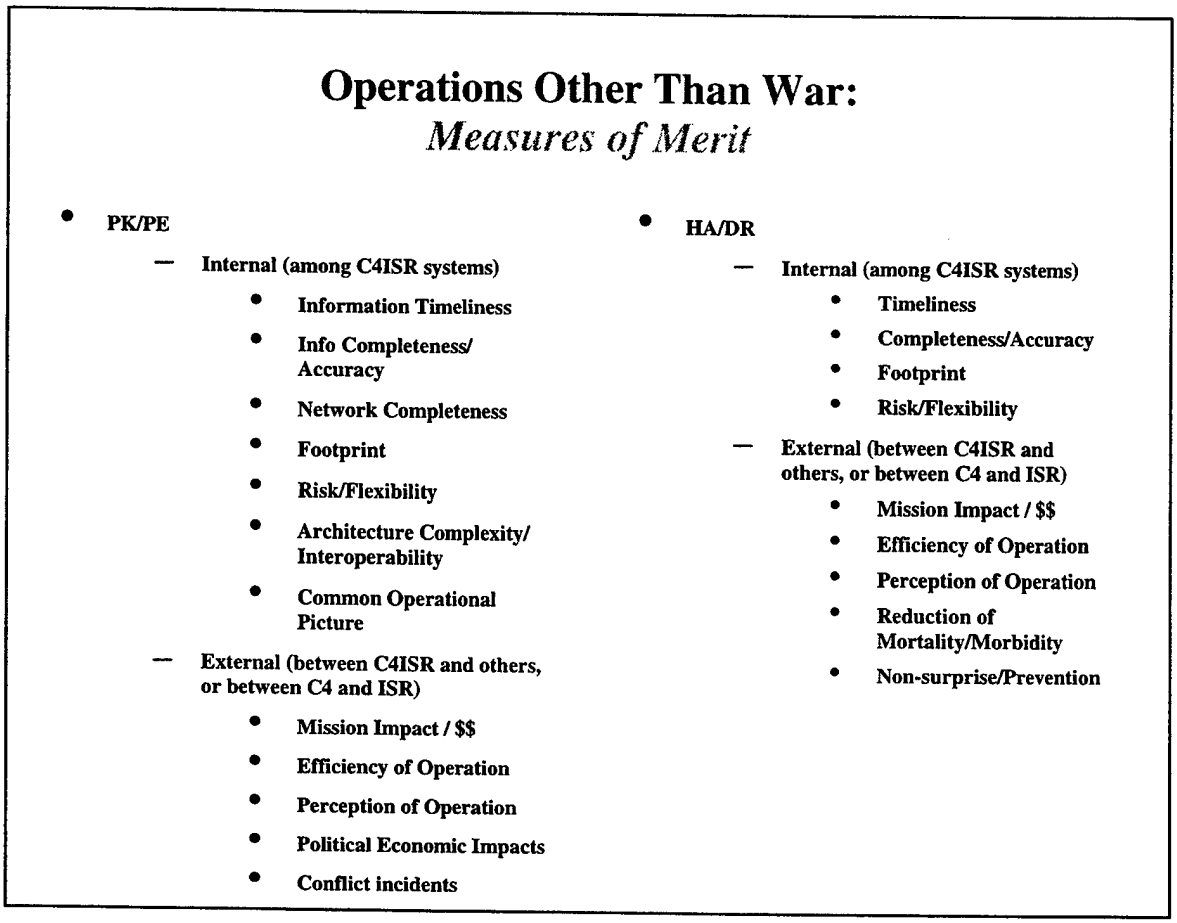
CLASS	MOE	DATA	SOURCES
Decision Making	Difference between perception & truth	Uncertainty / Risk Mitigation	Historical Assessment
	Right info ?	Trend & Pattern analysis	
	Timely info ?	Reaction time} ≤ Planning Decision time} Horizon	
Interoperability	# Interpreters required	Number	
	Network Connectivity	Systems, Networks	
	Communications Architecture Complexity	Bandwidth	
	Unity of Effort	Compliance with orders	
	COP		
	Responsiveness	Response Time	

Example Decomposition -- PK/PE (cont'd):

The mission completion category includes measures that address stability in the area of operations at the "measure of force effectiveness" level. The sort of measures developed (e.g. freedom of movement, economic and health trends) are diverse and may involve C4ISR in their completion. Therefore, C4ISR trades are viable and indeed important. Notably, they are challenging to analyze because tools to address these measures are scant. In the theater, current experience is to assess progress by trend analysis of data actually gathered. In planning cases, tradeoff analyses could be conducted by comparing potential effectiveness and cost of using alternative collection means. Trades based on impact on economic or cultural response in theater would currently be nearly impossible to assess.

Force protection measures lend themselves to tradeoff analysis since they can be addressed as effectiveness and cost issues. On the other hand, trades are more difficult to assess in the context of decision making support, since the scenarios and models are not widely available. Perception-based models are lacking in OOTW, just as they continue to be lacking for war fighting missions. In the area of interoperability, several measures can be addressed analytically since they are more closely related to network performance.

The sort of decomposition presented here illustrates some of the needs and possibilities for C4ISR tradeoff analysis. This example will apply for many situations, but is certainly not complete. Further work to extend these results is warranted.



Measures of Merit:

An overview of measures for PK/PE and HA/DR as applied to tradeoffs within C4ISR, and between C4ISR and other forces and systems is presented here. For trades within C4ISR, the measures frequently can be tied to measures of network performance. When this is true, typical analytic capabilities can be brought to bear.

When trades are to be conducted outside C4ISR, the measures are more MOFE-level. They will tend to differ for each of the mission areas in OOTW. they also are not supported by well-developed tools and models to conduct the analysis. Mission efficiency, in particular, will be related to economic and cultural measures. The theory and "transfer functions" from C4ISR effectiveness (or any other system or force capability) are lacking in most areas.

Operations Other Than War:
Tools

Analytic Purpose	Analytic Tools
Situation Assessment • Identify trends and patterns • Correlate across classes of MOEs • Political/economic/military • Ethnic/cultural/religious • Infer cause and effect • Track progress towards objectives	• Polling • Statistical Analysis • Sampling • Hypothesis Testing • Correlation • Data display • Data from past OOTWs/data mining tools • OOTW IPB
Support to Decision Making and C2 • Analyze alternative courses of action • Identify requirements • Reduce uncertainty • Improve timeliness • Assess quality of interoperability and comms	• Knowledge-based expert systems • Panels of experts • Virtual Information Centers • Wargaming • Collaborative decision making tools • Network analysis tools • Functional capability models • Lessons learned databases
Trade-Off Analysis • Support QDR-like force trades • Understand Total Force implications of OOTW	• Analytic frameworks • Scenarios • Data from past OOTWs • Expert judgment • Predictive capability models • OPTEMPO models

Tools:

This slide portrays the types of tools that are needed to analyze OOTWs. It is organized in terms of major analytic purposes. The first two purposes (situation assessment and support to decision making and C2) are inherent in the planning and conduct of OOTWs. Trade-off analysis addresses the broader issue that the workshop was charged to address: how to trade-off C4ISR against other categories of things, such as forces, to support QDR-level force trades.

Tools (cont'd):

While the tools that support these different purposes are organized into separate "bins" on the slide, in fact there are broad analytic needs that cross these categories. These include:

- Better ways to gather, analyze, and display data
- An understanding of past OOTWs and lessons learned
- Ways of tapping expert judgment. A promising example is the Virtual Information Center (VIC) concept for HA/DR being developed for PACOM
- Analytic frameworks for OOTW

While an end-to-end modeling approach to OOTW is well beyond the present state of the art, there is a clear need for tools and models that will do part of the job within the context of an analytic framework. For example, tools for HA/DRs that help to predict damage and casualties and generate requirements for medical supplies and personnel are invaluable. Within peace operations, models for assessing the performance of difference ISR capabilities or communications networks would be similarly helpful.

Operations Other Than War:
Relative Worth/Trade Offs

- **Trade-off taxonomy**
  - **Internal - within C3 and ISR**
  - **Internal - between C3 and ISR**
  - **External - between C4ISR and everything else (e.g., forces)**
- **Trade-offs are progressively more difficult from internal to external**
  - **MoMs go from relatively technical and quantifiable to operational/political and qualitative**
  - **Cause and effect relationships supporting higher-level MoMs become problematic**

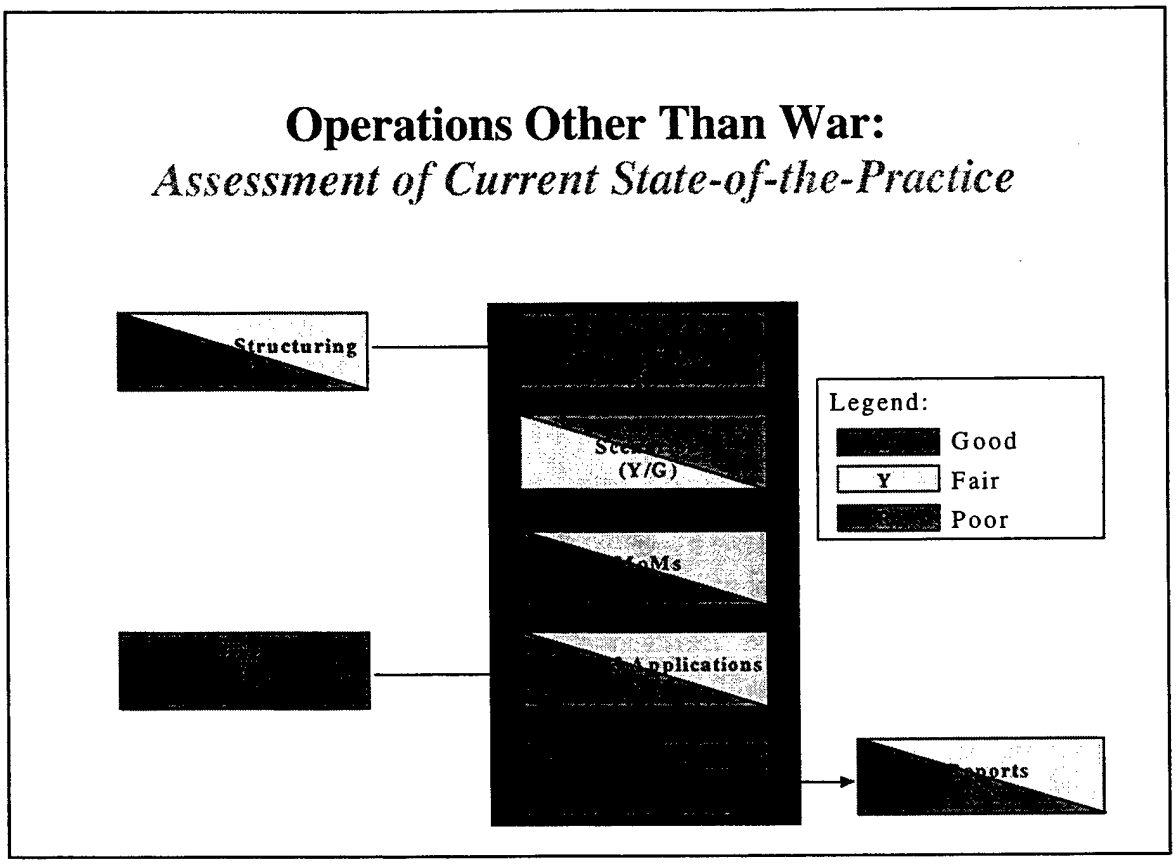
Relative worth/Trade-offs:

Trade-offs within the categories of ISR and C3 can be done in traditional ways that apply to other military operations. Measures of performance and effectiveness in these areas (such as quality, quantity, and timeliness for ISR) are well understood and relatively quantifiable. When one tries to trade-off ISR for C3 or, more broadly, C4ISR for other things such as maneuver forces, the capabilities are unlike, and causal relationships leading to the achievement of measures of force effectiveness or measures of policy effectiveness are highly uncertain. For this reason, the trade-offs that commanders make during every OOTW tend to be qualitative and informed by expert judgment rather than quantitative analysis. Qualitative trade-off judgments can be just as good as quantitative ones. In fact, in this area, they may be better than judgments based on trying to force the numbers to fit the problem. However, the ability to make qualitative trades, whether for operational or force planning, can be significantly improved by enhanced capabilities in the areas indicated by the slide:

- Definition of missions and requirements
- Exploitation of past lessons learned
- Databases of operational data
- Frameworks for analysis with tools and models integrated as appropriate

Operations Other Than War:
Relative Worth/Trade Offs (cont'd)

- **Easier trades (e.g., within ISR) may be helpful for programmatic and mission planning issues but are less likely to shed light on QDR-level force trades**
- **Trades of C4ISR with forces for OOTW require:**
  - **Better definition of missions and requirements**
  - **More organized exploitation of past lessons learned**
  - **Databases of operational data**
  - **Frameworks for analysis and appropriate supporting tools**



Assessment of Current State of the Practice:

It is not surprising to see that the state of the practice assessment shows many areas of shortfall.

- Structuring of the Problem rated a Yellow/Red. Recalling the focus of conducting analysis and tradeoffs of C4ISR assets, we see that there are few developed tools and procedures to apply in the general area of OOTW. Nevertheless, we acknowledge that these missions are being continually addressed day-to-day with apparent success.
- Human factors and organization rate a red because the human elements of C4ISR are not well modeled in OOTW. The human performance aspects of C4ISR performance metrics are less difficult than the responses of the actors in the OOTW area of operations. That is, the connectivity from C4ISR actions to cultural, religious, or other reactions is lacking, limiting the ability to conduct MOE-based analysis.
- Scenarios rated a yellow/green. The reason is simply that recent history has provided a large number of plausible planning scenarios. During the last QDR, a body of approximately 50 scenarios was developed for the Dynamic Commitment wargame series. The yellow results because the scenarios are not well documented and available for planning use at this time.

Assessment of Current State of the Practice (cont'd):

- Measures of Merit is rated as red, tending toward yellow. The workshop efforts as well as the operational missions over the last few years have now organized this area of investigation. Progress is being made in identifying these measures. Although the diversity of the OOTW missions makes this more difficult, trends are starting to emerge regarding what types are appropriate.
- Tools and applications rate red, trending toward yellow. In general, these missions are diverse and complex enough that no monolithic model is viewed as feasible or desirable. Rather, what is desired are sets of tools that address parts of the analyses directly and can be intelligently composed to address more complex questions. A few mission and force building tools are available and some C4ISR issues can be undertaken with standard network tools. However, the connection from C4ISR performance to mission effectiveness is missing, as was indicated under structuring the problem.
- Data is considered red. Evidence is found in the difficulty to access any data associated with any of the recent OOTW missions the US has been involved with. Furthermore, operational planning continues to be hampered by difficulty in rapidly accessing useful data. Due to the difficulties with measures, tools and data, it follows that areas like risk assessment would also rate red. Indeed, finding the marginal benefit or the risk associated with any analysis topic tends to be a difficult task.
- Finally, reporting rates a red trending toward yellow. Until recently, OOTW reports were hard to come by. During the QDR, efforts to assess past efforts were hampered by scant, inconsistent data and reports. Recent efforts have included greater efforts to gather data and report results. Further work is required. Mission objectives, forces, timelines, MoMs, as well as other data and analytic needs should be articulated so that future reports can provide useful information for the future.

Operations Other Than War:
Summary Observations

- **Diverse OOTW add to complexity**
  - **Of the mission area**
  - **Of the design of analysis tools**
  - **Of C4ISR tradeoff development**
- **Mission MoMs:**
  - **Are known, but vary widely by mission**
  - **Are "standard" for many trades within C4ISR**
  - **Are very difficult for tradeoff with Forces**
- **Not "ground lost" or "casualty ratio"**
- **Tradeoff Analysis focus varies**
  - **Operational-level (JTF) analysis most common**
  - **PPBS/Acquisition-level lacking**
- **Historical databases lacking**

Summary Observations:

The working group made several general observations in the course of its efforts. Many of them support the preceding discussion, but others need to be brought out separately.

First, we reiterate the fact that the diversity of OOTW missions adds complexity to C4ISR analysis. The breadth of the missions, and their different nature adds to the complexity in developing general approaches to conducting C4ISR analysis and complicates the process of designing tools to aid analysis. Then, we observe that the operational experience base exists to allow identification or development of MoM. These MoMs are known, but vary widely by mission and are definitely not "ground lost" or "casualty ratio." Many C4ISR-related trades lead to MoMs that are "standard" for such analysis. However, we see that MOFE measures are more difficult to assess in tradeoffs with other systems and forces.

We also note that we found it natural to discuss mission and tradeoff analysis in the context of JTF-level operations. Most of our discussions focused at that level. We see that these trades could easily be extended to acquisition-related system trades. However, for PPBS or QDR-level analyses, we think additional methodology is necessary since no single OOTW mission is likely to be the basis for force structuring or capability analyses.

Finally, our collective experience was that data access and historical data to support operational planning and analysis has been limited and limiting.

Operations Other Than War:
Recommendations

- **Establish an effort to advance our knowledge of OOTW and C4ISR in OOTW**
  - **Leading to analytic frameworks**
  - **Best Practices**
- **Continue efforts to ID analytic tool requirements to assess C4ISR support to OOTW**
- **Continue development of methods to better integrate OOTW analysis into DoD planning & programming**
- **Establish a common syntax & semantics to facilitate a comparison between study results**

Recommendations:

The working group was able to address the issues specified by the Terms of Reference for this meeting. The outline for generating MoMs and structuring C4ISR-centered analyses provides a useful step, but needs to be extended in both breadth and depth. As a result, we make the following recommendations:

Continue this process of methodology development. It should be a general effort to advance our knowledge of OOTW and C4ISR in OOTW, leading to analytic frameworks and best practices. This effort should also continue the process of identifying analytic tool to assess C4ISR support to OOTW.

At the DoD level, this effort should continue development of methods to better integrate OOTW analysis into DoD planning & programming. This need largely is derived from the fact that any single OOTW is too small and narrowly focused to drive force structure or major programming decisions.

Another aspect of these developmental efforts is to establish a common syntax & semantics to facilitate a comparison between study results. Such a framework will facilitate reviewing, comparing various missions and analyses, and will encourage more broadly based analysis.

Finally, a data support process is required to enable routine analysis. Procedures should be put in place to ensure data is gathered, stored and made available for analysis efforts.

Operations Other Than War:
Recommendations (cont'd)

- **Develop a deliberate approach to data collection**
  - **ID & prioritize needs**
  - **Establish collection mechanism**
  - **Establish repositories**
  - **Include Non-DoD sources**

Analyzing C4ISR for 2010

Infrastructure Assurance

Infrastructure Assurance:
The Problem

- **How does C4ISR support Infrastructure Assurance?**
  - **What is C4ISR?**
  - **What is infrastructure assurance?**
  - **What are the infrastructures?**
- **What are the infrastructure assurance information requirements?**
- **How can we analyze the C4ISR infrastructure to improve support of infrastructure assurance mission area?**

Working Group Tasking:

Here is the problem that the working group tried to address, and a partial answer:

In particular, how does C4ISR support Infrastructure Assurance?

- What is C4ISR and how does it fit into the context of Infrastructure Assurance?
- What are the physical and information requirements?
- And how can we analyze and use the C4ISR infrastructure to improve support of the Infrastructure Assurance mission area?

What is Infrastructure Assurance?

Infrastructure Assurance is the planning to improve the readiness, reliability and continuity of infrastructures such that they are:

- Less vulnerable to disruptions or attack;
- Harmed to a lesser degree in event of disruption or attack; and
- Can be readily reconstituted to re-establish vital capabilities.

Infrastructure Assurance:
Characterize C4ISR

- **Infrastructure Assurance/Critical Infrastructure Protection (CIP) is new and evolving mission area**
  - **PDD 63 signed May 1998**
  - **Our C4ISR knowledge from conventional warfare does not necessarily apply to infrastructure warfare**
- **Current DoD CIP Infrastructure Sectors**

• *Defense Info. Infrastructure*	• *Transportation*
• *Command, Control and Communications*	• *Health Affairs*
• *Intelligence, Surveillance and Reconnaissance*	• *Emergency Services*
• *Public Works*	• *Personnel*
• *Financial Services*	• *Space*
	• *Logistics*

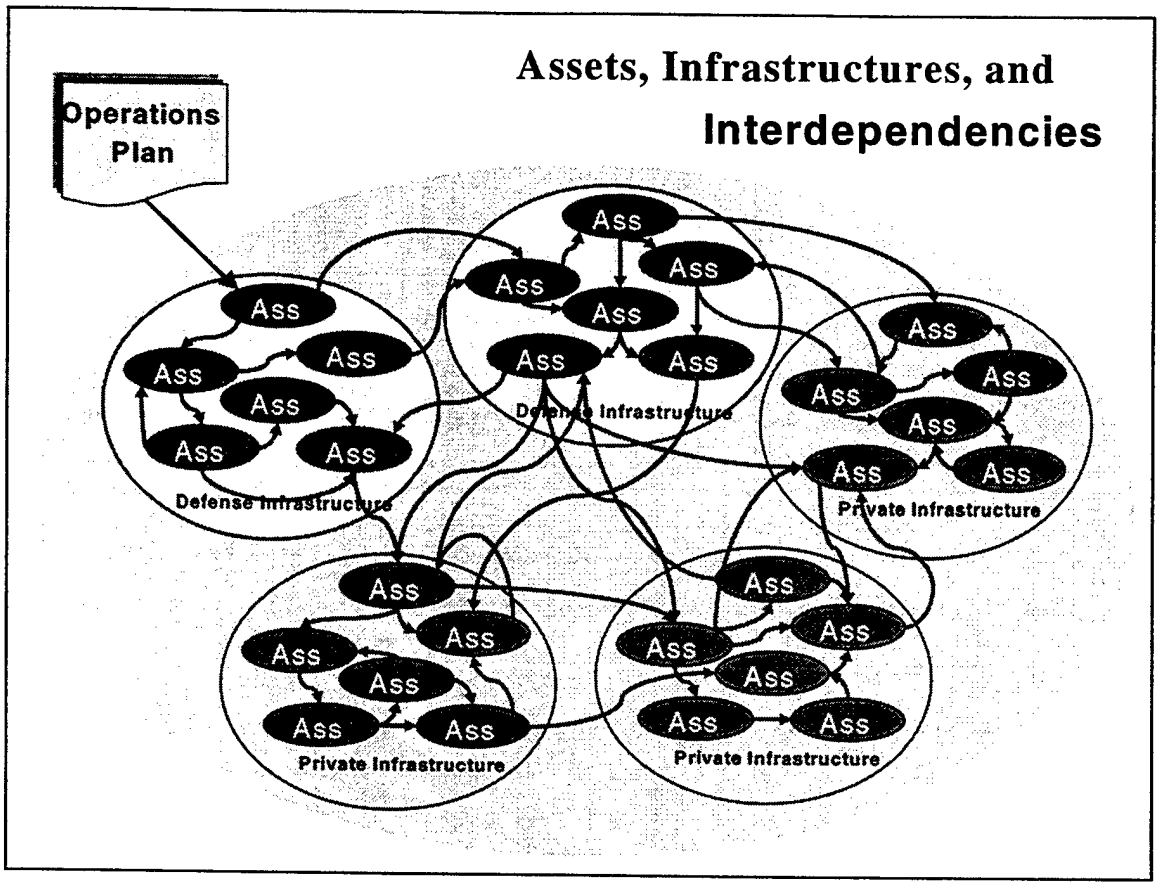
- **C4ISR must broaden to include law enforcement, OGA and the private sector**

Characterize C4ISR:

Infrastructure Assurance, until recently referred to as Critical Infrastructure Protection (CIP), is a relatively new and evolving mission area:

- Presidential Decision Directive (PDD) 63, which presents the overall scope of Critical Infrastructure Protection and calls for a national plan and structure to cope with the problem, was just signed in May of this year.
- It addresses a new kind of warfare, unlike what we have experienced in conventional warfare.
- To work the problem, the draft DoD CIP Plan divides DoD mission areas into 11 infrastructure sectors
  - 3 of those sectors comprise the C4ISR mission area
  - Each of the 3 C4ISR sectors must address all the physical, as well as cyber-related assets within that sector. For example we are not just looking at platforms and systems.
  - Additionally, these sectors cannot be considered in isolation from one another. Each is often dependent on the other to achieve its mission objectives. (e.g., electric power to run the computers, water to cool the computers, etc.) These services are routinely provided by commercial assets outside the government sector.

Therefore, the C4ISR community must broaden its vision to their dependencies on other government agencies and the private sector.



Assets, Infrastructures, and Interdependencies:

As we tried to demonstrate here, there are a myriad of interdependencies between the critical assets within certain Defense Infrastructures, other Defense Infrastructures, and the Private/Commercial Sector Infrastructures.

These dependencies and value chains must be well understood for analysis within the DoD lifecycle approach to the CIP problem (as defined in the draft DoD CIP Plan).

Infrastructure Assurance:
The DoD Strategy

Approach:

- **Identify Relevant Characteristics of Each Infrastructure that is Critical to Military Mission Success**
- **Analyze Military Plans to Identify Critical Infrastructure Assets**
- **Assess Vulnerabilities of Critical DoD Assets**
- **Redirect Resources to Reduce Prioritized Vulnerabilities**
- **Collaborate with Other Government Agencies and the Private Sector to Reduce Vulnerability of Private Sector Infrastructure Assets Critical to DoD Mission Success**

The DoD Strategy:

The DoD approach to the CIP or Infrastructure Assurance problem is to:

- Identify relevant characteristics of each infrastructure that is critical to military mission success.
- Analyze military plans to identify critical infrastructure assets.
- Assess vulnerabilities of critical DoD assets.
- Redirect resources to reduce prioritized vulnerabilities.
- Collaborate with other government agencies and the private sector to reduce vulnerabilities when services are provided from outside the DoD fence.

This should be done in the context of six (6) lifecycle phases that occur before, during and after events which may compromise or disrupt the services or mission accomplishment of a critical infrastructure.

Analysis, Assessment and Remediation are proactive preventive measures that take place continually. Indications and Warning primarily occur before an event. Mitigation occurs both before and during an event. Response occurs during an event and Reconstitution may start during an event, but is generally concentrated afterward.

Infrastructure Assurance:
C4ISR Must be Able to Support the IA Life Cycle

Example: Analysis/Assessment

- **Current Requirements**
  - **Architecture**
    - **Example: JCAPS, ISAAC**
  - **Data**
    - **Commercial Infrastructure (Electric Power, Communications, Transportation)**
      - **Example: NCS for Communications**
    - **Cyber Infrastructure: NIPC Certs**
- **Future Requirements**
  - **Data**
    - **Industry-Government Information Exchange**
  - **Wargaming/Simulation**

C4ISR Must be Able to Support the IA Life Cycle:

This and the next graphic are examples of how C4ISR possibly can support current and future infrastructure assurance requirements within a given lifecycle phase.

For the Analysis and Assessment Phase, operational architecture data on organizational missions, functions, structures, systems and their relationships to include information flows and dependencies can possibly be provided by such tools as the Joint C4ISR Architecture Planing/Analysis System (JCAPS) and the NCS for communications. For Cyber Infrastructure, the NIPC and various Certs are C4ISR components that support analysis and assessments. Future requirements will necessitate an exchange of industry and government information for wargaming and simulation exercises.

Infrastructure Assurance:
C4ISR Must be Able to Support the IA Life Cycle

Example: Indications & Warning

- **Current Requirements**
  - **Inter-Agency Information Sharing**
    - **Example: MDITS (Counter-terrorism)**
  - **Indicators (Criteria) for Minimum Operating Capability for Cyber Attack only**
- **Future Requirements**
  - **Government—Commercial Monitoring & Warning**
  - **Indicators (Criteria) to Assess Status of Affected Infrastructures, Operations, or Assets**
  - **Trace Ability**

C4ISR Must be Able to Support the IA Life Cycle (cont'd):

For the Indications and Warning Phase, inter-agency information sharing processes will need to be developed to satisfy current requirements. MDITS is an example.

Future requirements will necessitate:

- Government – Commercial Monitoring and Warning
- Indicators to assure status of affected infrastructures, operations, or assets, and
- Trace ability to the root of the problem.

Infrastructure Assurance:
Tools: Current Capability

- **DoD C4ISR tools generally lack the capability to facilitate detailed IA analysis because C4ISR requirements generally have not addressed the need to support Infrastructure Assurance.**
- **IA tools have been developed in response to Infrastructure Assurance community requirements and are effective for analyzing commercial infrastructure (power, transportation, communications, and information systems) and the military missions they support.**
- **Real-time infrastructure analysis hindered by poor integration of C4ISR and IA analysis tools**

Tools: Current Capability

Current tools capabilities and additional tool requirements are presented on this and the next graphic.

DoD C4ISR tools are currently lacking the capability to facilitate detailed infrastructure analysis. Therefore, separate tools have been developed to meet individual or specific needs. These tools are effective in the Infrastructure Assurance community for analyzing power, transportation, and communications. However, real-time infrastructure analysis is hindered by little or no integration of C4ISR and Infrastructure Analysis tools.

Infrastructure Assurance:
Tool Requirements

- **IA Tool Needs:**
  - **Integrated and Interoperable Tools**
  - **Comprehensive Models and Tools for Analyzing Defense Infrastructures**
  - **Models and Tools for Interdependency Analysis**
- **Need Collaborative Link between Infrastructure Analysis Centers and Warfare Centers**

Tool Requirements:

What is needed are integrated and interoperable tools, as well as comprehensive models for analyzing Defense Infrastructures. Models and tools are also needed to conduct interdependency analysis.

We also need to establish collaborative links between infrastructure analysis centers and warfare centers.

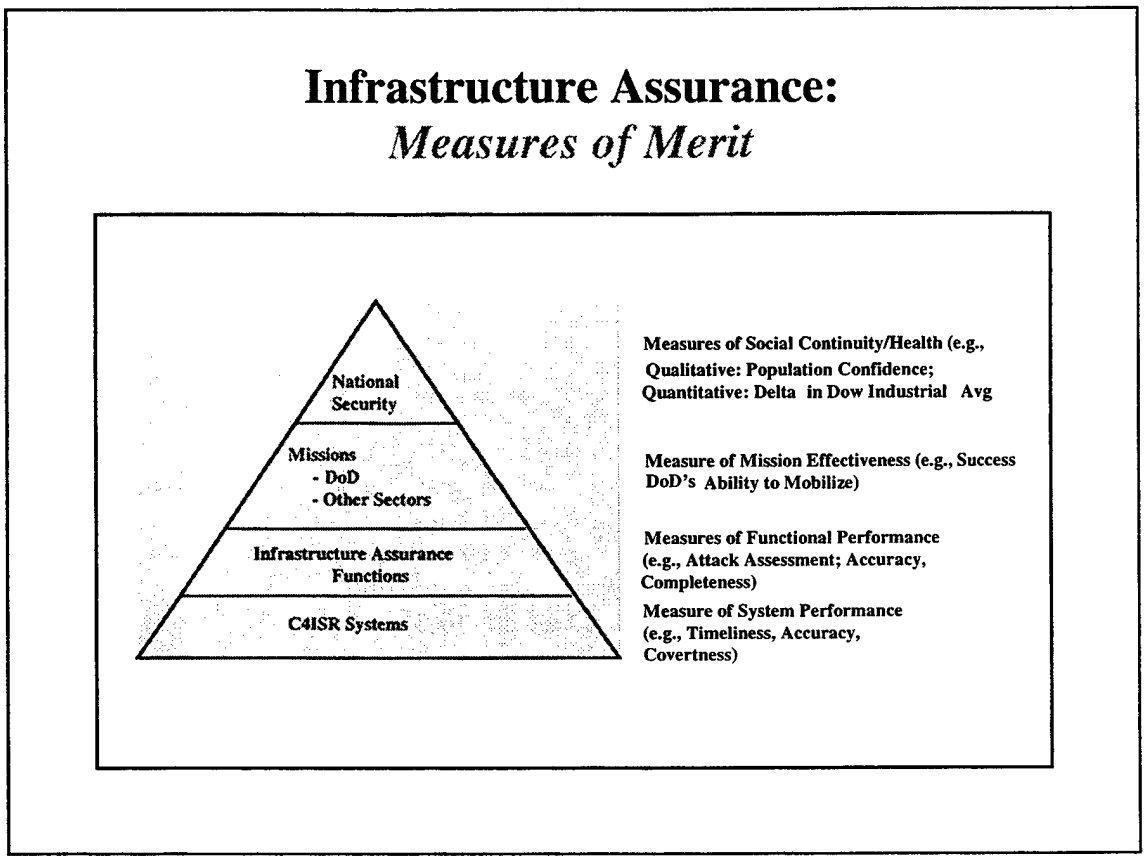
Infrastructure Assurance:
Relative Worth

Possible C4ISR Contributions:

- **Analysis and Assessment Tools**
- **Near Real Time Reporting Across All Sectors**
  - **I&W**
  - **Infrastructure Status**
- **Alternative Courses of Action**
- **Synchronized Information that Identifies the Criticality Attribute (e.g., Time) of Assets**
- **Information Dissemination and Sharing in Support of Infrastructure Assurance**

Relative Worth:

As suggested above, we believe the C4ISR community can provide some of the tools for architecture development and information sharing in support of Infrastructure Assurance. It also may provide some of the tools needed for near-real-time reporting across all sectors, particularly with respect to I&W and infrastructure status. Other C4ISR tools are available to provide information on alternative courses of action and synchronized information that identifies the critical attributes (e.g., time) of assets.



Measures of Merit:

We suggest four hierarchical measures of merit with respect to Infrastructure Assurance and its dependence on C4ISR as a basis for mission success and national security. At each level, the measures of merit must be consistent. Thus, for example, Infrastructure Assurance functions ("the lifecycle" activities of Assessment, Remediation, I&W, Mitigation, Response and Reconstitution) depend on our ability to perform timely, complete, accurate detection and assessment of an attack. To do this, the C4ISR systems upon which Infrastructure Assurance depends must meet system performance measures, such as

- timely;
- accurate;
- global collection of threat; and
- event data;

to support attack assessment and reporting back to affected locations, without raising suspicions of the attackers.

Infrastructure Assurance:
Key Issues and Questions

- **Definitions & Distinctions**
  - **What is a Critical Asset?**
  - **Infrastructure Protection vis-a-vis Force Protection**
  - **Reliance On Host Nation Infrastructures**
- **Buy-in**
- **Data - "Achilles Heel"**
- **Security**
- **Legal and International**

Key Issues and Questions:

Issues within IA revolve around internal discussions and decisions such as definitions and distinctions. For example, what really is IA? Where do we draw the line between infrastructure protection and force protection?

Issues that are internal and external revolve around "Buy-In," that is, getting our governmental entities both within DoD and other Federal, state and local agencies

- to share information
- to have a common understanding of IA

Buy-In also includes government to commercial industry issues:

- sharing proprietary information
- who pays?

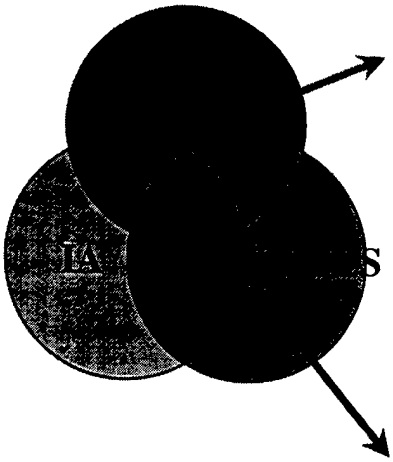
Issues of immediate relevance to MORS and the C4ISR question revolve around data, such as:

- Fidelity
- Getting Commercial Sector to Provide Data (Often Proprietary)
- Getting Government Organizations to Provide Data (Asking vs. Tasking)
- Central Data Repository

And of course, there are Security issues too broad and too deep to discuss at this point, but obvious from the C4ISR perspective and now the IA perspective.

There is a substantial CONUS-focused legal question. And there are substantial international issues, again too broad and too deep to discuss at this point, but relevant to the future of IA.

Infrastructure Assurance:
Recommendations



- **MORS continue to emphasize Infrastructure Assurance as an essential element of C4ISR (and other) analyses and wargaming and simulation exercises**

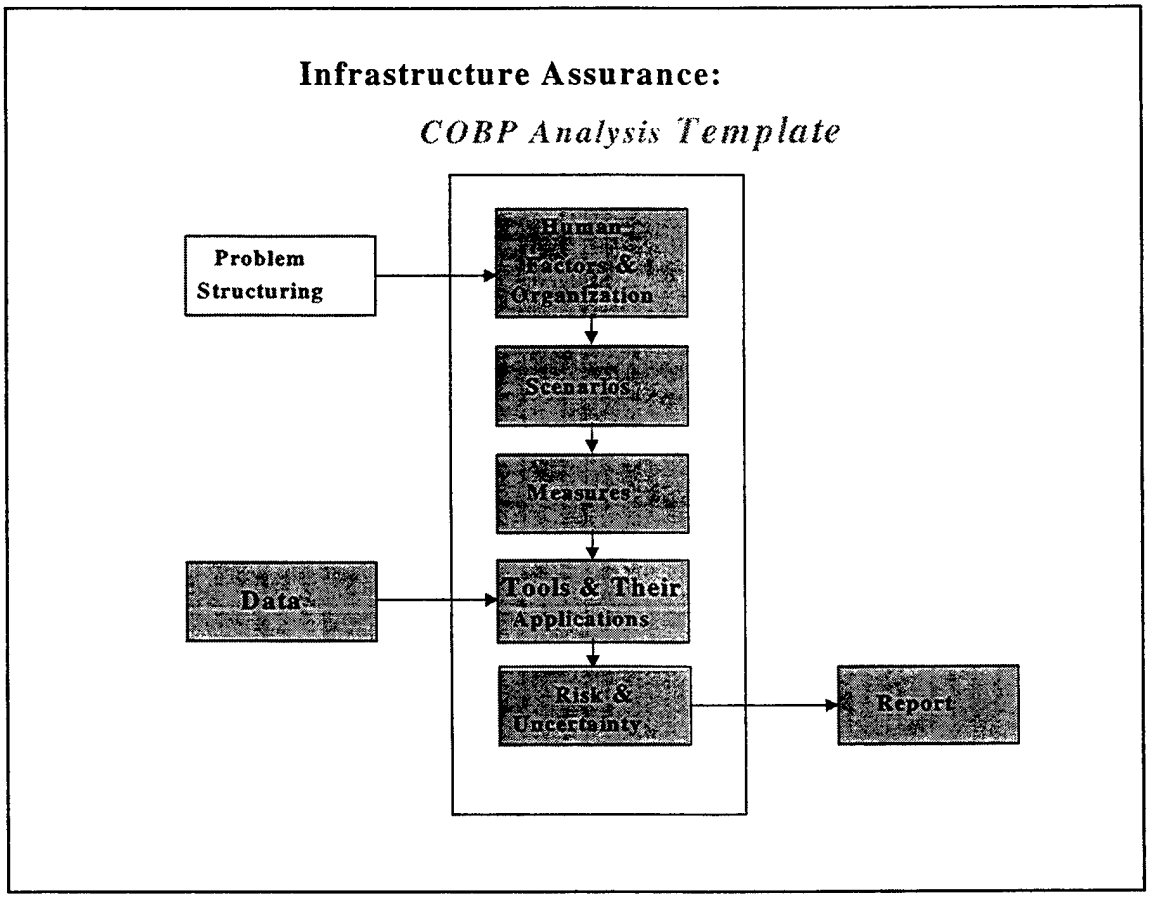
- **Joint C4ISR and Infrastructure Assurance community analysis of the application and integration of complementary tools**

Recommendations:

While there are quite a few recommendations one can see deriving from the C4ISR-IA connection, we have focused on two (2).

- The first is that MORS and its connections to the education community, such as the National Defense University, continue to actively pursue the inclusion of Infrastructure Assurance in its modeling/simulation assessment activities.

- And the next is that we in the IA community and the C4ISR community begin to develop mutual understanding of our requirements in order to develop integrated tools systems, etc.


Infrastructure Assurance:
COBP Analysis Template
Problem Structuring
Human Factors & Organization
Scenarios
Measures
Data
Tools & Their Applications
Risk & Uncertainty
Report

Analyzing C4ISR for 2010

Peacetime Engagement

Peacetime Engagement (PE):
Working Group Members

• Bruce Powers (Chair)	Office of CNO, N816
• Dean Free (Co-Chair)	Office of CNO, N816
• Kevin Brandt	MITRE Corporation
• Trena Covington	Johns Hopkins University, Applied Physics Lab
• LCDR Marty Keutel,	USN Office of CNO, N6C
• Dr Steve Pilnick	EDO-Technology, Inc.
• Dr Dave Schrady	Naval Postgraduate School
• CDR Mark Tempestilli, USN	Office of CNO, N6C
• Chris Vogt	Navy Warfare Development Command

Peacetime Engagement (PE):
Presentations

- **"*Maritime Battle Experiments*," Chris Vogt, NWDC**
- **"*Network Centric Warfare Concepts*," Dean Free, N816**
- **"*Navy RMA 2020 Wargame Results*," CDR Bill Valentine, N81**
- **"*Evaluating Mission Effectiveness in OOTW*," Adam Siegel, CNA**
- **"*Economic Benefit of Forward Presence*," Dr David Schrady, NPS**
- **"*Design Considerations/MOE for Linking C4ISR with M&S*," Kevin Brandt, MITRE**
- **"*Net Collective C^2*," CDR Randy Bowdish, Office of CNO, N51**

Peacetime Engagement (PE):
Definition

The application of resources (including forces) in peacetime to make shooting less likely. Successful PE would promote other goals:

- **Stability of commerce**
- **Deterrence**
- **Separation of potential belligerents**
- **Exercises with (potential) allies**

Definition:

- No current Joint Staff definition of Peacetime Engagement (PE).
- Current related Joint Staff definitions:
  - **Overseas Presence**: The totality of US military instruments of power deployed overseas. It is that portion of the force postured overseas to support performing the full range of military activities comprised of permanent forces, temporary forces and infrastructure.
  - **Engagement**: All military activities involving other nations intended to shape the regional security environment in peacetime. Engagement is comprised of operations, exercises and other foreign military interactions.
- The above definition characterizes PE as deterrent in nature and includes benefits of deterrence as broad goals that are measurable to some degree.

Peacetime Engagement (PE):
Pre-Conflict C4ISR Performance Measures

- **Threat located**
  - **% of total OOB**
  - **% of number deployed OOA**
  - **% in vicinity of blue opareas**
  - **% threat weapons close**
  - **False target rate impact**
- **% needed info available**
  - **At partners' command centers**
  - **At US command centers**

Pre-Conflict C4ISR Performance Measures:

These represent a sample of C4ISR measures in the pre-conflict phase of a campaign. One would also need to consider:

- Threat intentions
- Threat strategy
- Centers of gravity for the threat
- Courses of action to deter the threat — need to understand our options and the threat's response; "effects-based" options, not just an attrition-based approach

Bottom line: ISR is MUCH more than a collection of numbers.

Peacetime Engagement (PE):
Lessons Learned

- **C4I is a pillar of PE**
- **Needs to be adaptive to PE circumstances**
- **Installing, operating, commanding and maintaining network may become the most important functions**
- **Less easy to predict C4I patterns 15 years hence than it is to predict platforms in inventory**
- **Info ops highest utility will be in PE**

Lessons Learned:

Discussion led to the list of lessons learned on this and the next two slides. The discussion centered around the insights provided by the seven briefings received by the working group, plus discussions of the purpose and objectives of the workshop.

Peacetime Engagement (PE):
Lessons Learned (cont'd)

- **Intel prep of battlefield is conducted during PE**
- **PE provides means to partially validate models of warfare**
- **PE not a lesser included case of warfare**
- **Greater use and size of C4I systems may bring greater C4I vulnerability**
- **Deploying C4ISR increasingly follows model of naval deployment**

Peacetime Engagement (PE):
Coalitions

- **Greater number of potential partners in PE than in specific MTWs**
- **Interoperable C4I required for coalitions**
- **Reliance on coalition wartime capabilities requires peacetime investment in C4I**
- **Coalition interoperability improves war fighting capability**

Coalitions:

These are conclusions about coalitions that resulted from discussion of PE in the broader context.

Peacetime Engagement (PE):
Key Issues and Questions

1. **After Cold War, the spectrum of potential conflict has broadened**
   - **The probability of occurrence of events on this spectrum may be differently distributed**
   - **Data collection and analysis of that issue should follow**
2. **Naval Postgraduate School research suggests major benefits ($10Bs) in savings on oil prices by prompt deployment of naval forces in crises. Can the scale of benefits for deployment of C4ISR be similarly identified (e.g., AWACS deployment impacting prices of drugs from Colombia)?**

Key Issues and Questions:

1. The nature of the world, the threat, has changed drastically since the end of the cold war. The distribution of risk of warfare is quite different, with more uncertainty about the probabilities of specific threats. There is a need to collect data and develop the distribution of events on the current and future spectra of conflict.

2. The Naval Postgraduate School study identified significant potential savings on oil prices by early deployment of naval forces. It is possible that early deployment of C4ISR systems could provide similar benefits.

Peacetime Engagement (PE):
Key Issues and Questions (cont'd)

3. **The less an event looks like war, the less able we are to articulate its governing processes. C4ISR in PE requires drawing in political constraints/considerations to a degree greater than for other points on the spectrum. This suggests peculiar data requirements for military/C4ISR commanders in PE settings.**

4. **For PE events, the cyclical process (define MOM, measure sensitivity, collect data, evaluate data, report) needs to also capture critical C4ISR data and effects.**

Peacetime Engagement (PE):
Recommendations

- **Develop broadly-accepted TOR for PE: definitions, objectives, goals, distinguishing relationships from OOTW to MTW**
- **Develop CSOP for PE**
- **Develop MoMs and data collection checklists for PE**
- **Expand JULLS formats and databases to include C4ISR data**

Recommendations:

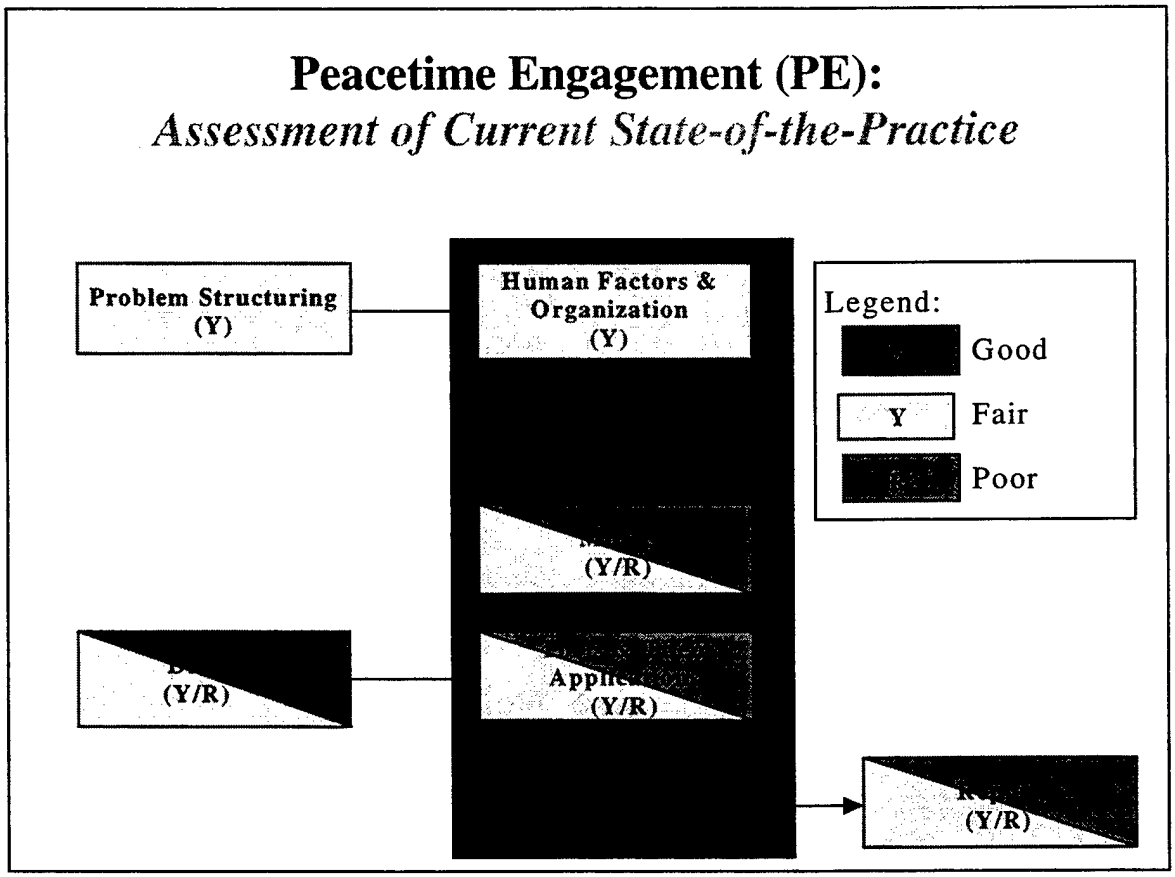
- Recognizing PE as an important mission area, with attendant principles and distinguishing relationships, will assist in identifying the peculiar tasks of PE, and garnering funding for their successful undertaking.
- Common Standard Operating Procedures must account for the many differences (historical, cultural, financial, educational, etc.) that exist in the many countries that we engage during PE operations. "One size fits all" is not the answer. We need to KNOW our PE "targets" much better and tailor each engagement to that particular country. Specific C4ISR exchanges are good candidate elements for tailored PE.
- Expansion of the Joint Uniform Lessons Learned database to include C4ISR data and information will help long term analysis of C4ISR issues.

Peacetime Engagement (PE):
Recommendations (cont'd)

- **Study the impact of deploying C4ISR in peacetime**
  - **Assess utility of C4ISR deployment on its own**
  - **Assess how early C4ISR deployment facilitates early combat power by follow-on forces**

Recommendations (cont'd):

The results of such a study, successfully completed, should help determine the value added by C4ISR systems. The study should also address how a robust C4ISR exchange program helps build coalitions and therefore serves as a significant deterrent.



Assessment of Current State-of-the-Practice:

Scenarios represent the only good news on this slide. In all other areas, assessment of the current state-of-the-practice is discouraging. There is much work to be done to develop measures of effectiveness and tools and to collect data relevant to proper analysis of C4ISR issues related to PE.

Peacetime Engagement (PE):
Summary

KEY ISSUES

- **Since the cold war, the spectrum of potential conflict has broadened. The probability of occurrence of events on this spectrum may be differently distributed. Data collection and analysis of that issue should follow.**
- **The less an event looks like war, the less able we are to articulate its governing processes. C4ISR in PE requires drawing in political constraints/ considerations to a degree greater than for other points on the spectrum. This suggests peculiar data requirements for military/ C4ISR commanders in PE settings.**
- **For PE events, the cyclical process (define MOM, measure sensitivity, collect data, evaluate data, report) needs to also capture critical C4ISR data and effects.**

RECOMMENDATIONS

- **Develop broadly-accepted TOR for PE: definitions, objectives, goals, distinguishing relationships from OOTW to MTW**
- **Develop CSOP for PE**
- **Develop MoMs and data collection checklists for PE**
- **Expand JULLS formats and databases to include C4ISR data**

Summary:

- **KEY ISSUES**
- The nature of the world and the threat, has changed since the end of the Cold War. The distribution of risk of warfare is quite different, with more uncertainty about the probabilities of specific threats. There is a need to collect data and develop the distribution of events on the current and future spectra of conflict.
- **RECOMMENDATIONS**
- Recognizing PE as an important mission area, with attendant principles and distinguishing relationships, will assist in identifying the peculiar tasks of PE and garnering funding for their successful undertaking.
- Common Standard Operating Procedures must account for the many differences (historical, cultural, financial, educational, etc.) that exist in the many countries that we engage during PE operations. "One size fits all" is not the answer. We need to KNOW our PE "targets" much better and tailor each engagement to that particular country. Specific C4ISR exchanges are good candidate elements for tailored PE.
- Expansion of the Joint Uniform Lessons Learned (JULLS) database to include C4ISR data and information will help long term analysis of C4ISR issues.

Analyzing C4ISR for 2010

Architectures

Architectures Working Group

Overview

- **Traditional analytical paradigms are platform-centric**
- **Architectures allow you to treat C4ISR as a platform**
- **Therefore allow evolution to *ARCHITECTURE-CENTRIC* analysis**

Overview:

Analytical paradigms have traditionally focused on evaluating the effectiveness of a platform or system. Architectures provide a structured approach for describing and understanding a system-of-systems associated with a specified domain, such as C4ISR and in doing so allow that domain to be considered as if it were an entity. Using the architecture construct enables our analytical focus to evolve from being platform-centric to become architecture-centric.

Architectures: *Current Status*

Architectures are an evolving discipline
-- part science and part art

PROs

- **Provide an understanding of how information is used to accomplish work and how Information Technology supports work**
- **Form the basic data and data relationships that can support C4ISR issue analysis through various analytical techniques to include Modeling and Simulation**

CONs

- **Generally are static snapshots in time and hand crafted; difficult to reuse**

An architecture should not be an end in itself
....but should be a means to an end.
Should have a well-defined purpose and objective.
stated at the beginning of the effort.

Current Status:

While major architectural precepts are well defined and generally well accepted, architectures are a still evolving discipline which demand a combination of both art and science.

From the positive perspective, architectures help us understand the relationship and dependencies among tasks, operational elements accomplishing those tasks and the information flow that needs to occur among the operational elements to accomplish the tasks appropriately. They enable us to describe the systems and communications that support that information flow across nodes and in doing so, enable the understanding of how Information Technology supports work.

Architecture descriptions form the basic data set of activities, operational elements, information flows, nodes, systems and communications that support a wide variety of C4ISR issue analyses using various techniques to include Modeling and Simulation.

The use of architectures may be limited or restricted because they generally provide a static perspective and represent snapshots in time. They traditionally have to be developed on an individual basis and the information is difficult to capture for reuse in related efforts.

Architectures have too frequently been seen as an end in themselves when their true value is as a means to an end. A successful architecture effort must begin with a well-defined purpose and objective.

Architectures: *Potential*

- **Architectures can provide a seamless bridge between the C4ISR user and developer communities.**
- **Operational architecture can capture operational requirements in a fashion that allows consistent traceability to design specifications.**
- **Symbiotic relationship between analysis and architectures which need to be emphasized and strengthened**

Potential:

The traceable linkage across the architecture products provide an audit trail relating and translating mission effectiveness requirements of the C4ISR user to system requirements to which the system developer must build.

Because of that traceable linkage, operational architectures are able to capture operational requirements in a way such that design specifications can be consistently traced to those requirements.

The relationship between architectures and analyses using a variety of techniques is only beginning to be explored. The close and mutually beneficial relationship between architecture and analysis need to be emphasized and strengthened.

Architectures: *Keys to Realizing Potential*

- **Must be able to access, reuse and manipulate data across a wide range of stakeholders**
  - **Users**
  - **Developers**
  - **Acquirers**
- **Must integrate human factors into architecture: People are an integral part of architectures**
- **Need to represent threat more overtly to include analysis of adversary as well as friendly (interactive)**
- **Tools are critical**
  - **Better visualization**
  - **Greater flexibility**
  - **More usable by the operational subject matter experts**
- **Must be able to better articulate the "so what" (operational impacts) of architectural analysis to warfighters and to decision makers**

Keys to Realizing Potential:

In order to realize the full potential of architectures, the various stakeholders from system users to developers and acquirers, must be able to access the architecture data, manipulate it and reuse it in a variety of ways.

Current architecture constructs do not overtly recognize and portray the impact of human factors. Because people are an integral part of any architecture, architecture constructs need to be expanded to more specifically represent human factors.

Threat also needs to be represented more overtly in architectures.

Getting data from a hardcopy text presentation to a structured softcopy presentation is essential and will enable the use of automated tool. The use of tools is critical to provide better visualization, greater flexibility and to make the data more usable to operational subject manner experts.

Architecture description developers must perceive that their primary objective is not just the accumulation and presentation of the architecture data but the analysis of that data to identify the "so what", i.e. the operational impacts and to better articulate those impacts to warfighters and decision makers.

Architectures: *Measures of Merit*

- **Still very immature, promising efforts at early stages**
- **Must be able to establish quantifiable relationship between measures of performance and operational measures of effectiveness/outcome**

Key to Architecture-Centric Analysis
Still tend to think in terms of platforms,
must learn how to transfer that to system-of-systems

Measures of Merit:

Currently there are no well-conceived and realized measures of merit associated with architectures.

There are three aspects of architectures which potentially could be measured:

(1) how well the architecture description has been developed,

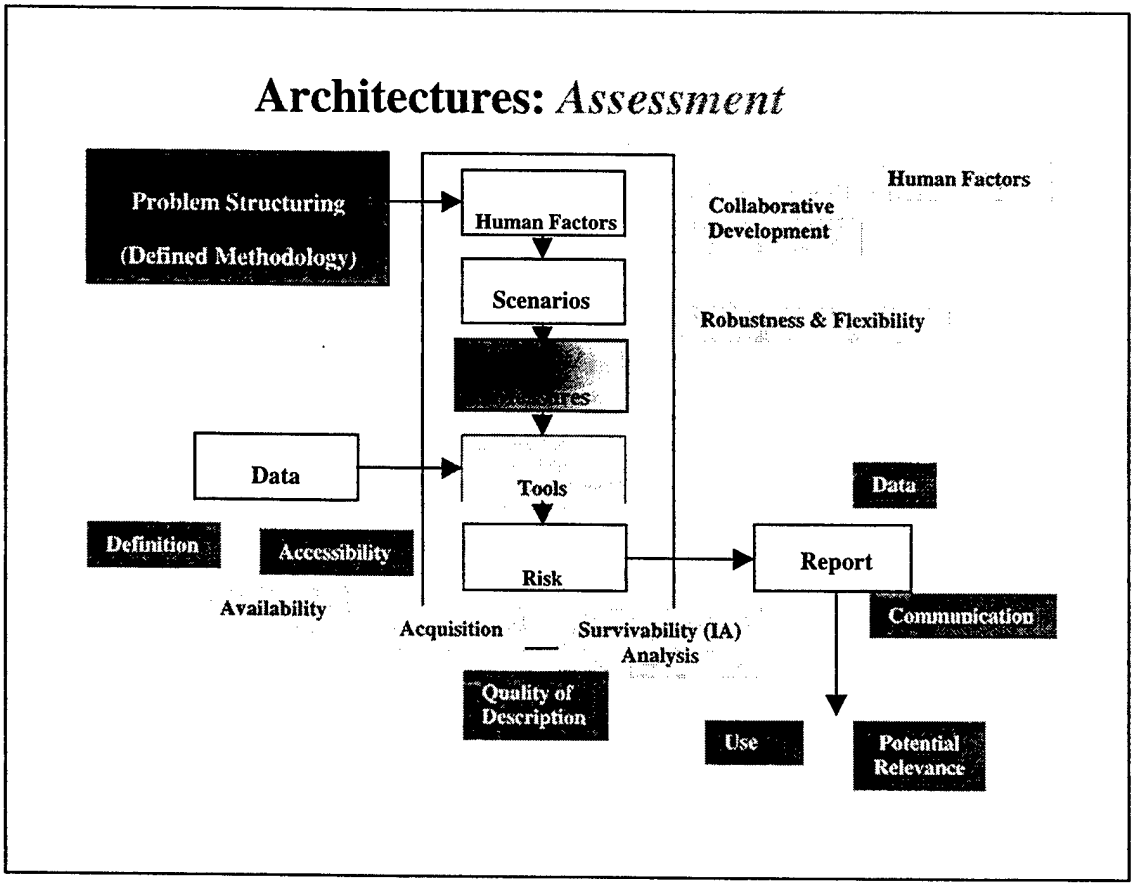
(2) to what extent is the architecture description being used and

(3) the value of the architecture in achieving C4ISR goals and objectives.

The third aspect is considered the most meaningful and the most difficult to quantify. It is the aspect most addressed in ongoing efforts. A metric for this aspect must be able to establish a quantifiable relationship between measures of performance for individual systems and operational measures of mission effectiveness associated with the architecture's system-of-systems.

The community appears to just be in the initial stage of addressing metrics for architectures. While current efforts, such as those by John Hopkins, Boeing and OASD (C3I), are very immature but they show promise.

The ability to measure the value of a specified architecture in achieving mission effectiveness is key to architecture-centric analysis.



Assessment:

The above graphic provides a color-coded assessment of the current state of the art for architectures. There is a well-defined methodology in place -- the *C4ISR Architecture Framework has* been mandated for use in DoD.

While there is some capability to portray human factors via architectures, it is not well defined. In terms of the human factor aspect of architecture development, there is a need for a greater ability for collaborative development.

Scenarios can be portrayed in architectures but additional robustness and flexibility is needed.

Measures of Merit are only just now beginning to be addressed.

While there are a variety of tools available, a coherent tool set is yet to be achieved.

Architecture data is well defined, but there is no centrally-managed or maintained architecture data repository. Thus gathering data for architecture descriptions generally requires a great deal of primary collection effort.

Architectures have the capability of reducing risk in acquisition efforts and supporting analysis of information assurance, but generally are not used to the extent possible.

Developers are generally quite good at presenting the architecture data in a report but are frequently not successful in communicating the "so what" of an architecture.

Architectures: *Summary*

- **Architectures are an evolving discipline**
  - **part science and part art**
- **Methodology well defined but still evolving**
- **Potential for architecture-centric analysis**
  - **structured data repository**
  - **automated tools**
- **Need greater emphasis on the "so what"**
- **Measures of Merit still in very early stages but some promising beginnings**

Summary:

Architectures are an evolving discipline which has reached a certain level of maturity but will continue to evolve. Developing architecture descriptions requires both science and art.

While the methodology is well defined in the C4ISR Architecture Methodology, it will continue to evolve based on use across DoD.

There is great potential for architecture-centric analysis but a structured data repository and automated tools are critical to achieve that potential.

Architectures must not be static descriptions but require greater emphasis of the "so what."

Measures of Merit are in very early stages but there are promising beginnings across the community.

Analyzing C4ISR for 2010

Analytical Techniques and Tools

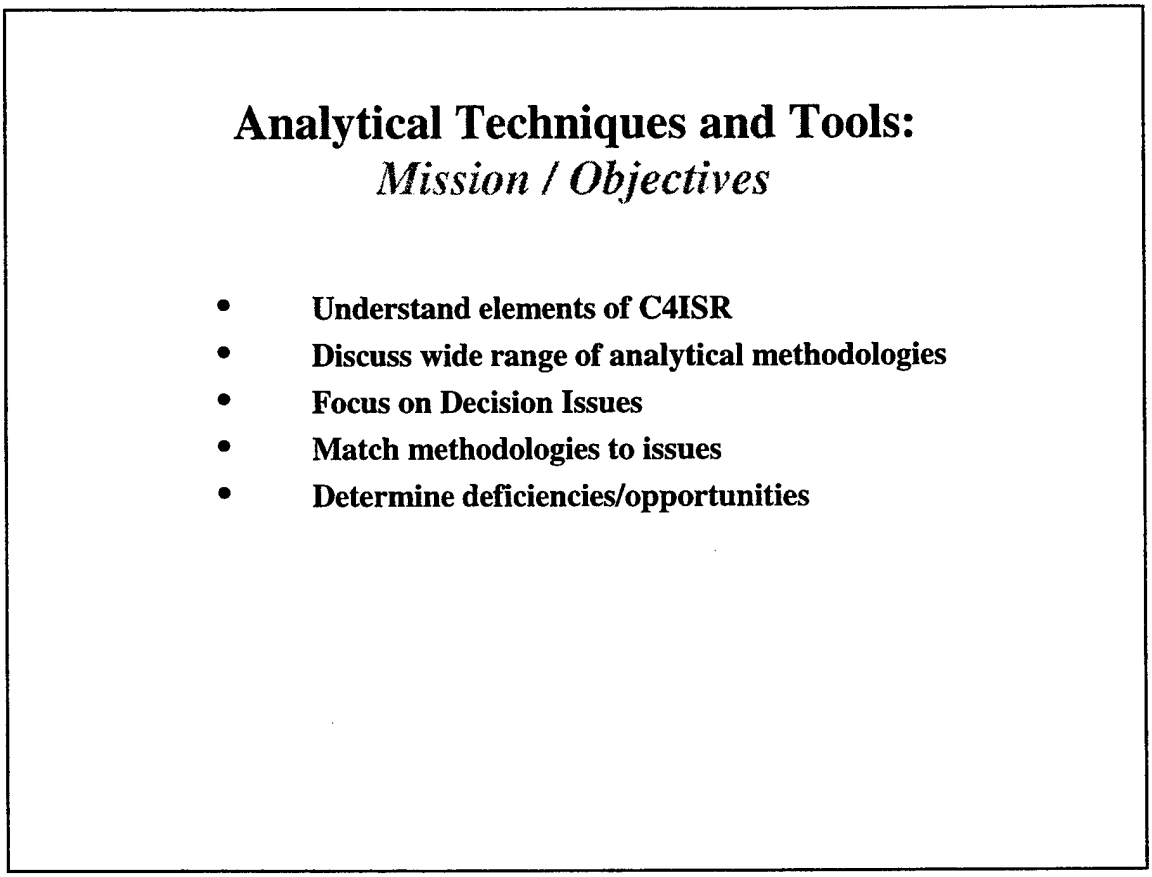
This is the Final Out brief from the Analytical Techniques and Tools Working Group. Dr Al Brandstein was the Chair and Dr Roy Rice was the Co-chair. Members of the Working group are listed in the Attendees list. Special thanks goes to Mr Steve Ritacco and Captain Geof Maron for their superb work in recording the discussions and preparing this briefing.

Analytical Techniques and Tools:
Outline

- **Introduction**
- **Taxonomy**
- **Summary**

Outline:

Preparatory remarks are included in the Introduction. This details our mission and objectives for our Working Group. It also outlines the context by which we focused our discussions. Next is a detail of the taxonomy we devised to frame how we discussed the uses, misuses, deficiencies and opportunities for improvement for our analysis methodologies and tools. Finally, we summarize our two days of discussions with a list of findings.



Mission / Objectives:

Our first objective was to come to some common understanding of the elements of C4ISR. This was from an operational, analytical, and modeling standpoint. This allowed us to focus on the analysis needs. Then we received several briefings covering a wide range of C4ISR topics and analysis approaches. With this range of applicable methodologies in mind, we discussed the various decision issues or questions that decision makers are asking now, or will probably be interested in, in the future.

Our next effort was to match some of the relevant methodologies to the particular decision issues. This then allowed us to discuss some of the specific deficiencies or opportunities to improve the state-of-the-art.

Analytical Techniques and Tools:
Actions of Group

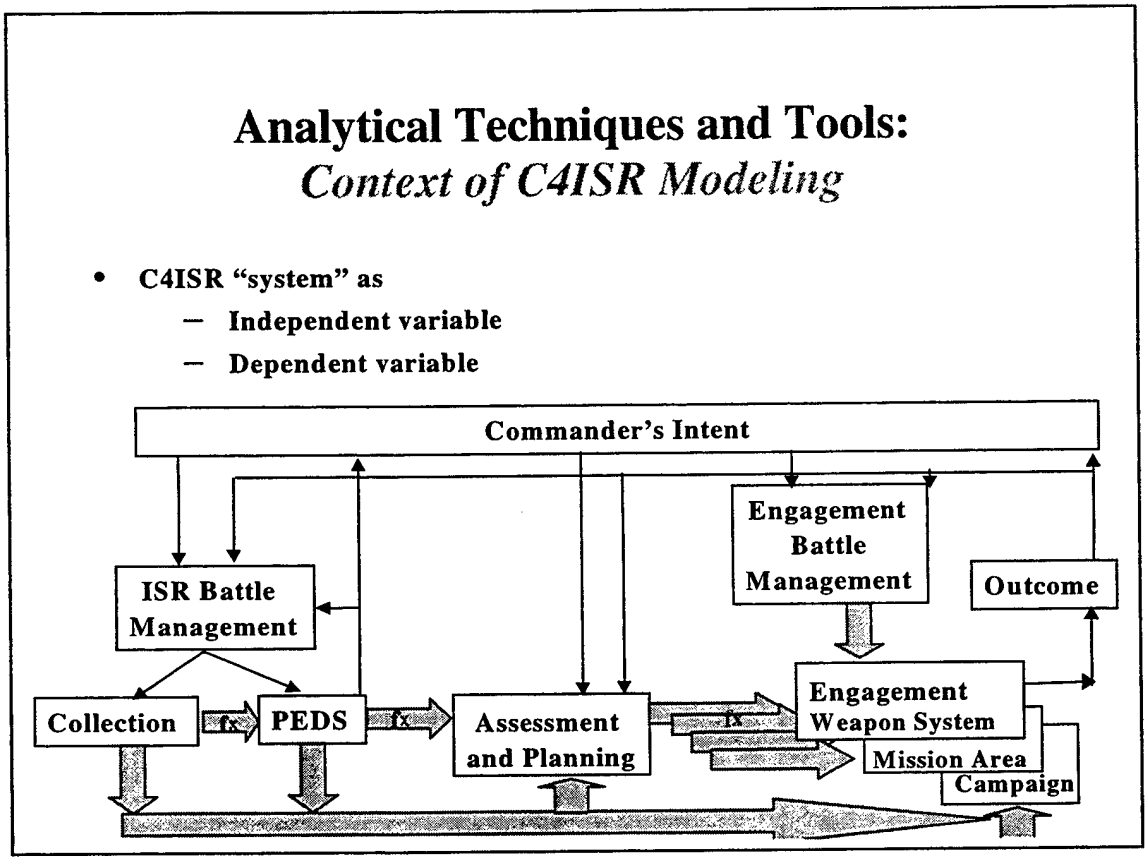
- **Methodologies**
  - **JWARS; NETWARS; Optimization; Complex Adaptive Systems; Systems Dynamics; etc.**
  - **Discussions**
- **Develop taxonomy of Decision Issues**
- **Rate the "Starr" Chart**
- **Glean pearls of wisdom**

Actions of Group:

The first day of the workshop, we heard presentations from several attendees on analytical methodologies they are using, modeling efforts they are involved in, and current/future capabilities. These were briefings by:

- LTC Dan Maxwell - JWARS
- LTC Pat Dye - NETWARS
- Roy Rice - C4ISR Optimization using the Sensor Platform Allocation Model (SPAM)
- Capt Geoff Maron - an application of Complex Adaptive Systems (CAS)
- Charlie Hall - Linking C4ISR to Military Effectiveness
- Steve Upton - Generative Analysis: Using Composable Agent-based Simulations for Future C4ISR Concept Exploration
- Steve Kolek - Battlefield Communications Network Modeling
- Robie Samanta Roy - Analyzing C4ISR on Strike Mission Performance
- Evan Ellis - Systems Dynamics Modeling to Represent C4ISR

The discussions that followed these presentations led us to develop a taxonomy by which to address many of the Decision Issues. This provided a context by which we rated the various areas of the chart Dr Starr provided as a guideline in his plenary presentation.

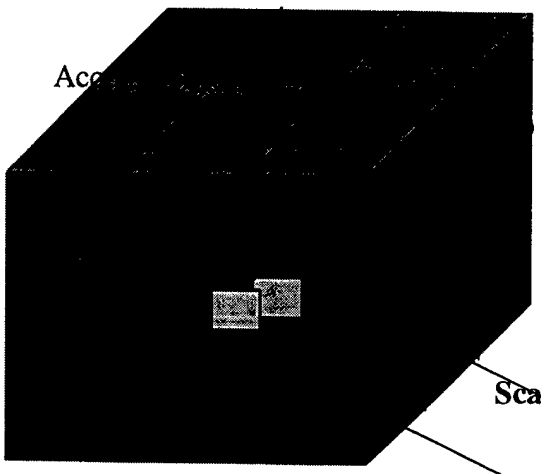


Context of C4ISR Modeling:

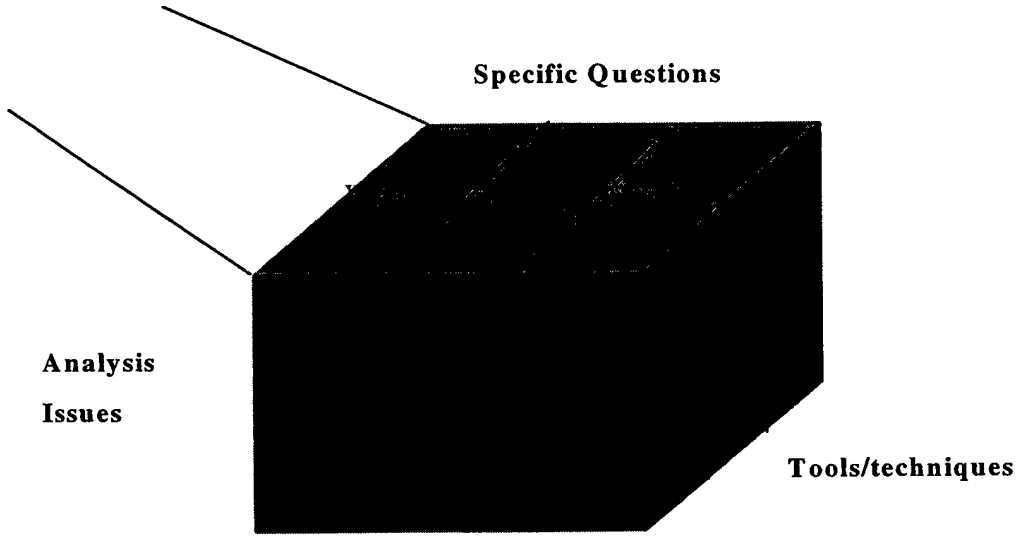
The discussions quickly led us to conclude that our analyses of relevant C4ISR "systems" includes C4ISR "systems" as independent variables and dependent variables. What we mean here is that we often perform analyses of the specific elements of C4ISR. We compare alternative sensors, platforms, architectures, and their performance. This is where C4ISR "systems" could be considered as independent variables. There are also the cases where we analyze other parts of our application of military force (forces, tactics, doctrine, etc.) where C4ISR "systems" must play but are not the analytical topic of interest. They must be represented and accounted for properly in our analyses and models. This is where they would be considered dependent variables.

In that context, we used the depiction here to represent the elements of the C4ISR "system" from an operational, analytical, and modeling perspective.

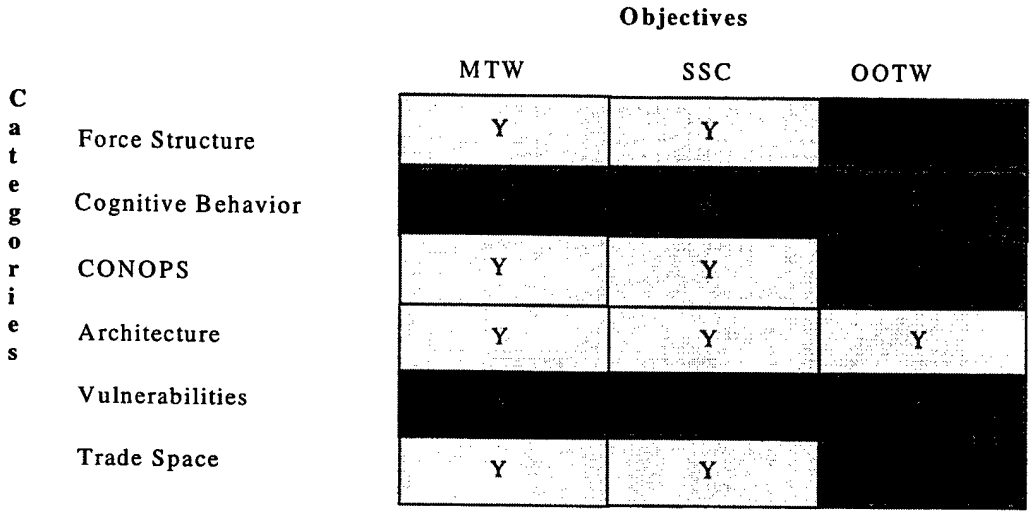
Analytical Techniques and Tools:
Areas of C4ISR Analysis



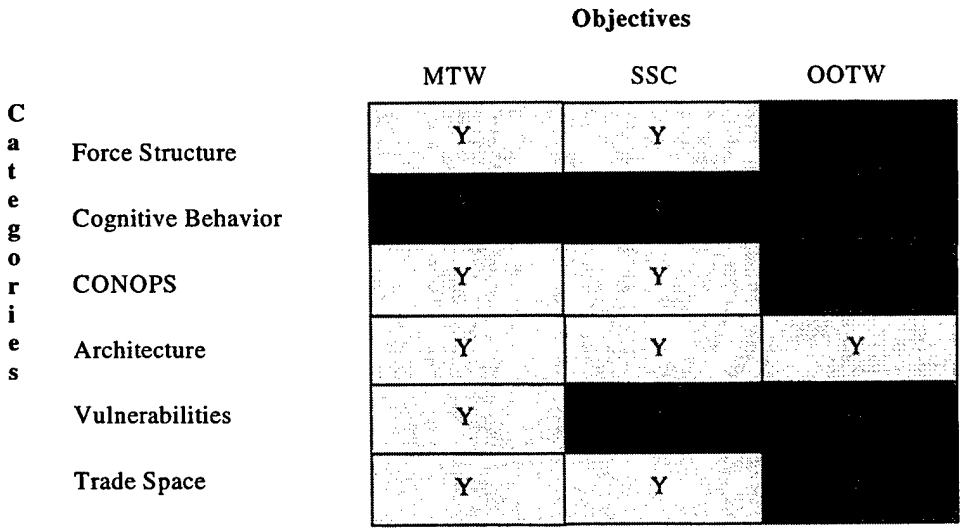
Analytical Techniques and Tools:
Within Each Area (Cube)



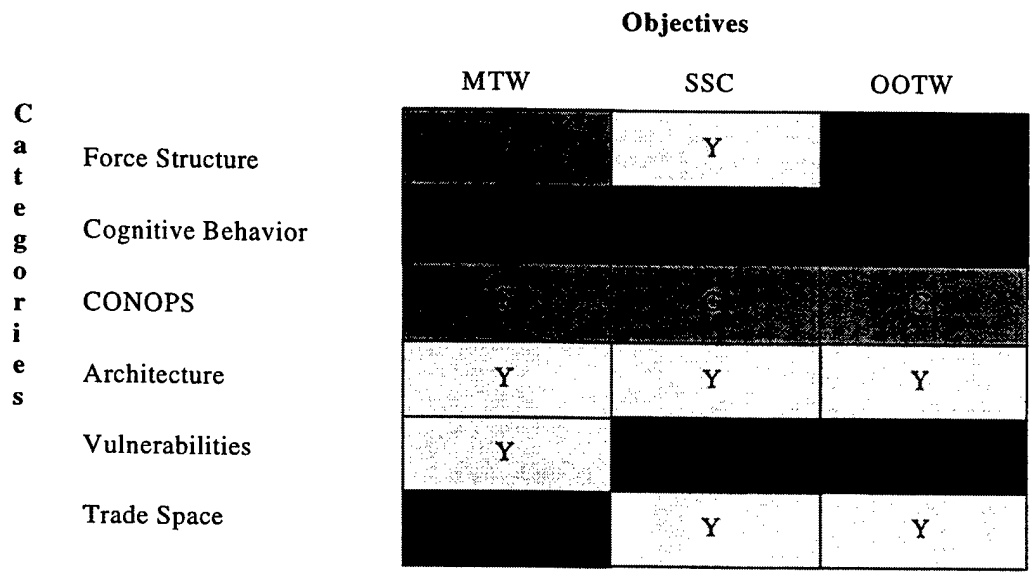
Analytical Techniques and Tools:
Acquisition Slice



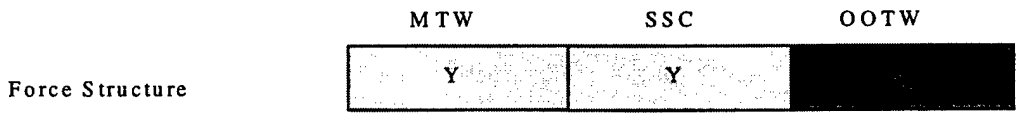
Analytical Techniques and Tools:
Operational Slice



Analytical Techniques and Tools:
POM / Budget Slice



Analytical Techniques and Tools:
Acquisition / Force Structure



- MTW & SSC
  - Room for improvement
  - Scenarios rated Red, Data rated Red
- OOTW
  - Data lacking
  - Gaping void below high level documents
  - Tools cannot be found even if objectives are ID'd
  - No architecture exists for interagency C^2 (NGO & GO)

Analytical Techniques and Tools:
Acquisition / Cognitive Behavior

	MTW	SSC	OOTW
Cognitive Behavior	[redacted]	[redacted]	

- Hard to get cognitive behavior effects
- Too recent
- Exploratory
- We don't understand the process

Analytical Techniques and Tools:
Acquisition / CONOPS

	MTW	SSC	OOTW
CONOPS	Y	Y	

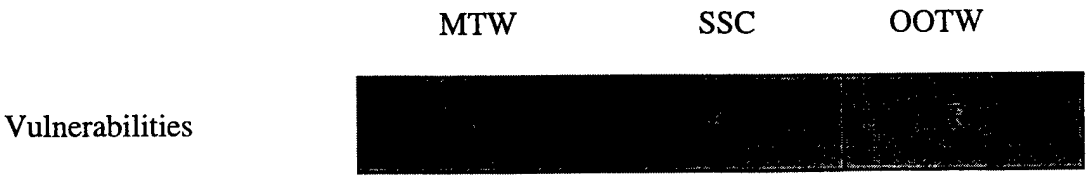
- MTW / SSC
  - Doctrine is wired into the tools
  - C4 deficiencies exist within the tools
- OOTW
  - Tools are lacking

Analytical Techniques and Tools:
Acquisition / Architecture

	MTW	SSC	OOTW
Architecture	Y	Y	Y

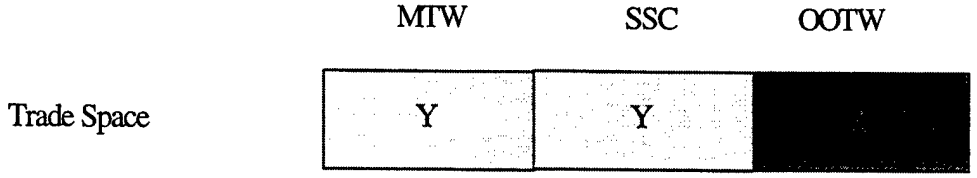
- Data is difficult to obtain
  - Especially in OOTW (NGO and coalition)

Analytical Techniques and Tools:
Acquisition / Vulnerabilities



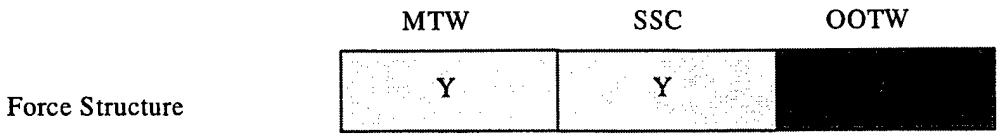
- Computer security / information warfare tools are required
  - Not much interest in this area
  - We have little experience or basis for creating these tools

Analytical Techniques and Tools:
Acquisition / Trade Space



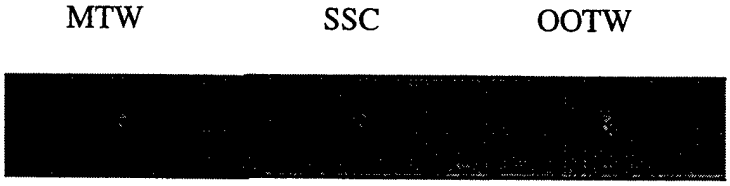
- No tools exist for architecture trade space
- OOTW
  - Data lacking
  - Gaping void below high level documents
  - No architecture exists for interagency C^2 (NGO & GO)

Analytical Techniques and Tools:
Operational / Force Structure



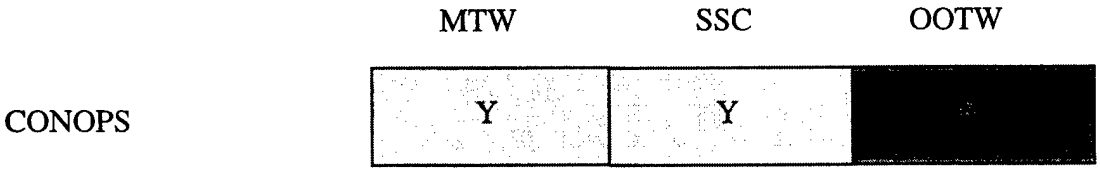
- Greenish tint to the yellow
  - This is the area in which we have the most expertise
- Don't model ambiguity well
  - We know we don't do this
- Data remains a problem
  - Availability
  - Abstraction

Analytical Techniques and Tools:
Operational / Cognitive Behavior



- This area has significant potential
  - Effects of stress
- Continue development of tools in this area
  - Measures to exploit our experiences
- Need data collection methodology

Analytical Techniques and Tools:
Operational / CONOPS



- We know methodologies
- Don't have the resolution in our tools to provide sufficient insights

Analytical Techniques and Tools:
Operational / Architecture

	MTW	SSC	OOTW
Architecture	Y	Y	Y

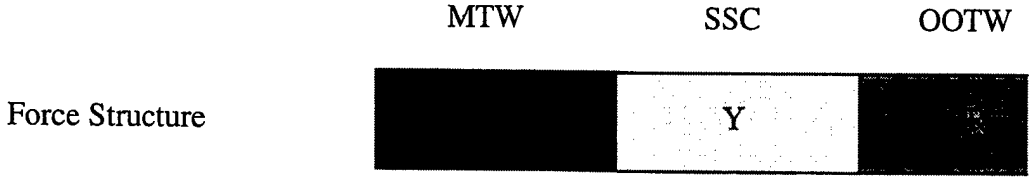
- Requires concentration of near term investment
- Measures of Merit required to feed to operational decision makers
- Tools need to be dynamic
  - Economic pressures
  - COTS impact on force structure
    - Commercial satellite systems, ...

Analytical Techniques and Tools:
Operational / Vulnerabilities

	MTW	SSC	OOTW
Vulnerabilities	Y	[redacted]	

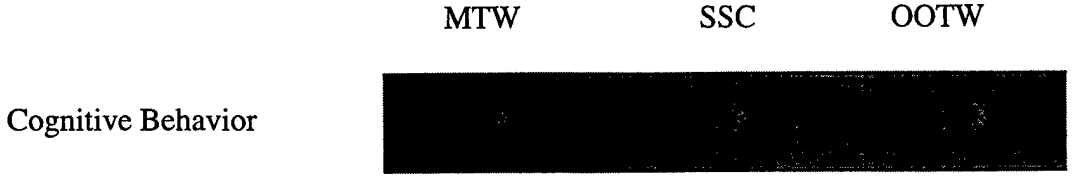
- Need to be able to study the sensitivities of our architectures to our assumptions

Analytical Techniques and Tools:
POM/Budget / Force Structure



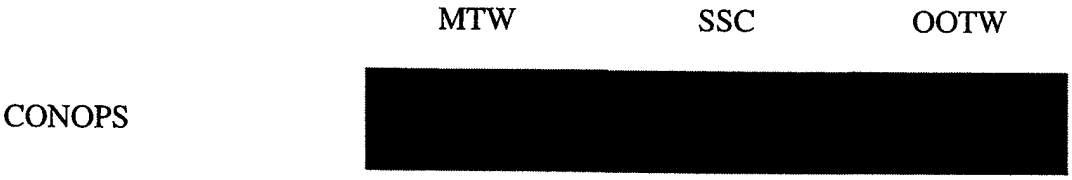
- Low level MoM acceptable, but aggregate measures are poor
- Scenarios fair for high levels, poor for low levels
- Tools are good at mission level
- Tools are poor at the joint level, across missions, and among services
- Data is fair

Analytical Techniques and Tools:
POM/Budget / Cognitive Behavior



- Ability in area is in infancy stages
- Data is poor
- Tools are poor
- Measures are fair

Analytical Techniques and Tools:
POM/Budget / CONOPS



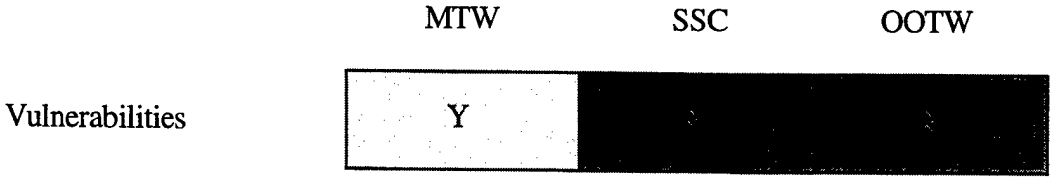
- CONOPS specified enough for budgeting purposes
  - Consideration of broader scenarios is poor
- Tools may be poor, but data and measures are good

Analytical Techniques and Tools:
POM/Budget / Architecture

	MTW	SSC	OOTW
Architecture	Y	Y	Y

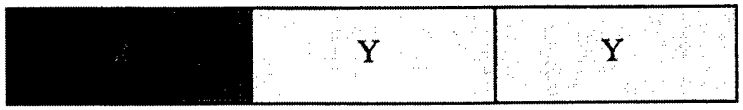
- No agreement on MoMs across scenarios, services, and different C4ISR systems
- Tools are good
- Data is good to fair

Analytical Techniques and Tools:
POM/Budget / Vulnerabilities



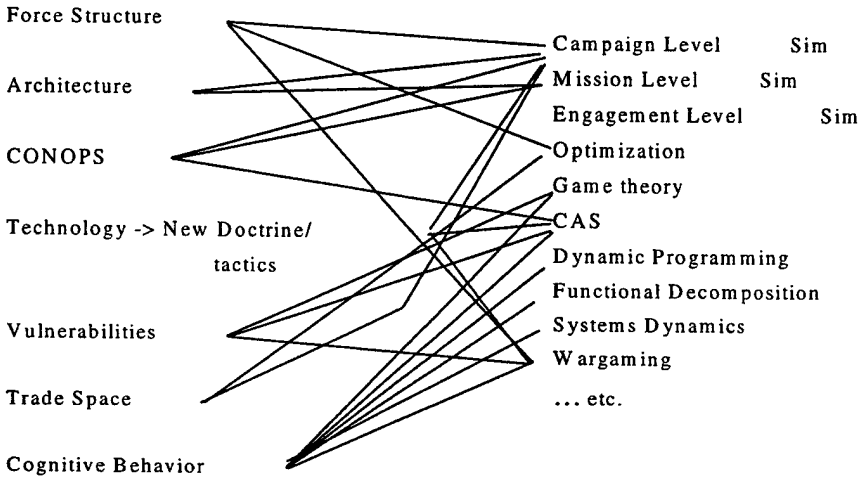
- Questions about levels of redundancy and levels of fitness are not well described
- Tools that show the effects of non-linear interactions and the ability to measure their impact on complex systems are lacking.
- Data is poor
- MOMs are poor
- Tools are fair

Analytical Techniques and Tools:
POM/Budget / Trade Space



- Good to fair within mission and functional area
- Poor to fair between missions and services
- MoMs fair
- Tools fair
- Data poor

Analytical Techniques and Tools:
Matching Issues and Methodologies



Analytical Techniques and Tools:
Coalitions

- **Greater number of potential partners in PE than in specific MTWs**
- **Interoperable C4I required for coalitions**
- **Reliance on coalition wartime capabilities requires peacetime investment in C4I**
- **Coalition interoperability improves war fighting capability**

Coalitions:

These are conclusions about coalitions that resulted from discussion of PE in the broader context.

Analytical Techniques and Tools:
Key Issues and Questions

1. **After Cold War, the spectrum of potential conflict has broadened**
   - **The probability of occurrence of events on this spectrum may be differently distributed**
   - **Data collection and analysis of that issue should follow**
2. **Naval Postgraduate School research suggests major benefits ($10Bs) in savings on oil prices by prompt deployment of naval forces in crises. Can the scale of benefits for deployment of C4ISR be similarly identified (e.g., AWACS deployment impacting prices of drugs from Colombia)?**

Key Issues and Questions:

1. The nature of the world, the threat, has changed drastically since the end of the cold war. The distribution of risk of warfare is quite different, with more uncertainty about the probabilities of specific threats. There is a need to collect data and develop the distribution of events on the current and future spectra of conflict.
2. The Naval Postgraduate School study identified significant potential savings on oil prices by early deployment of naval forces. It is possible that early deployment of C4ISR systems could provide similar benefits.

Analytical Techniques and Tools:
Key Issues and Questions (cont'd)

3. **The less an event looks like war, the less able we are to articulate its governing processes. C4ISR in PE requires drawing in political constraints/considerations to a degree greater than for other points on the spectrum. This suggests peculiar data requirements for military/C4ISR commanders in PE settings.**

4. **For PE events, the cyclical process (define MoM, measure sensitivity, collect data, evaluate data, report) needs to also capture critical C4ISR data and effects.**

Analytical Techniques and Tools:
Recommendations

- **Develop broadly-accepted TOR for PE: definitions, objectives, goals, distinguishing relationships from OOTW to MTW**
- **Develop CSOP for PE**
- **Develop MoMs and data collection checklists for PE**
- **Expand JULLS formats and databases to include C4ISR data**

Recommendations:

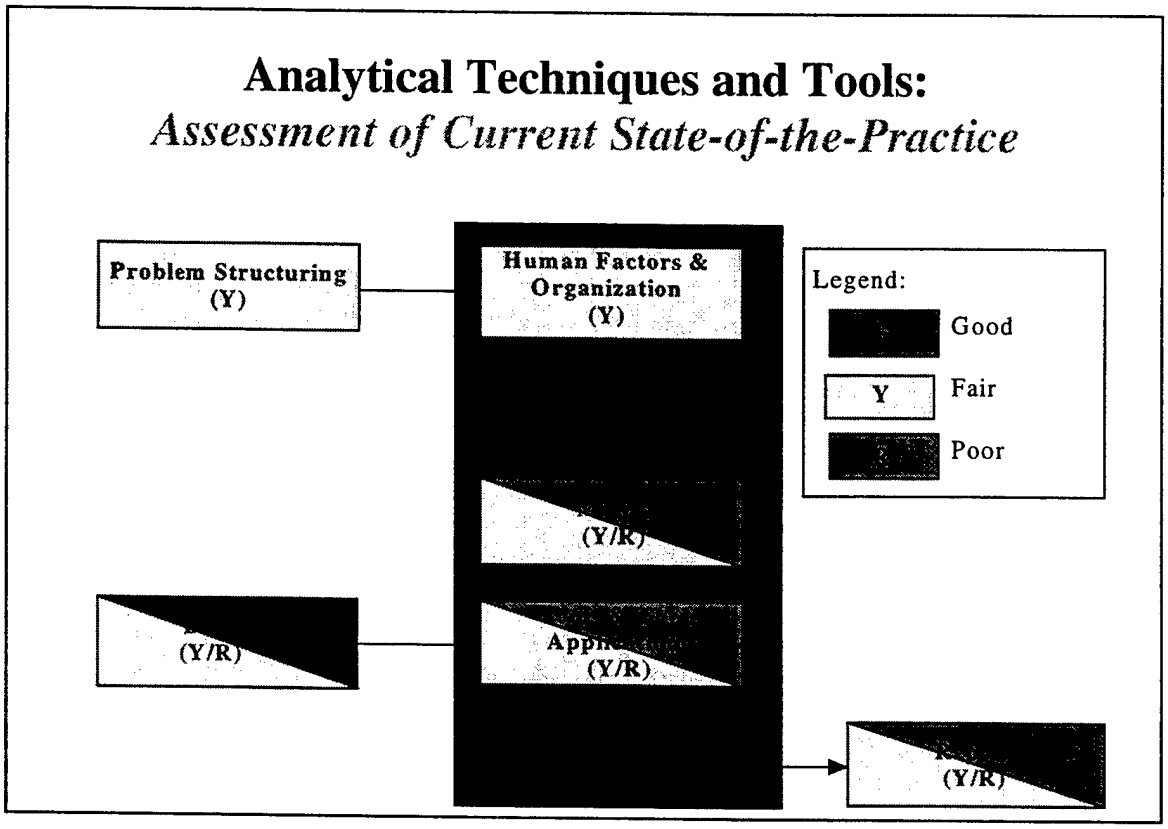
- Recognizing PE as an important mission area, with attendant principles and distinguishing relationships, will assist in identifying the peculiar tasks of PE and garnering funding for their successful undertaking.
- Common Standard Operating Procedures must account for the many differences (historical, cultural, financial, educational, etc.) that exist in the many countries that we engage during PE operations. "One size fits all" is not the answer. We need to KNOW our PE "targets" much better and tailor each engagement to that particular country. Specific C4ISR exchanges are good candidate elements for tailored PE.
- Expansion of the Joint Uniform Lessons Learned database to include C4ISR data and information will help long term analysis of C4ISR issues.

Analytical Techniques and Tools:
Recommendations (cont'd)

- **Study the impact of deploying C4ISR in peacetime**
  - **Assess utility of C4ISR deployment on its own**
  - **Assess how early C4ISR deployment facilitates early combat power by follow-on forces**

Recommendations (cont'd):

The results of such a study, successfully completed, should help determine the value added by C4ISR systems. The study should also address how a robust C4ISR exchange program helps build coalitions and therefore serves as a significant deterrent.



Assessment of Current State-of-the-Practice:

Scenarios represent the only good news on this slide. In all other areas, assessment of the current state-of-the-practice is discouraging. There is much work to be done to develop measures of effectiveness and tools and to collect data relevant to proper analysis of C4ISR issues related to PE.

Analytical Techniques and Tools:
Summary

KEY ISSUES

- **Since the cold war, the spectrum of potential conflict has broadened. The probability of occurrence of events on this spectrum may be differently distributed. Data collection and analysis of that issue should follow.**
- **The less an event looks like war, the less able we are to articulate its governing processes. C4ISR in PE requires drawing in political constraints/ considerations to a degree greater than for other points on the spectrum. This suggests peculiar data requirements for military/ C4ISR commanders in PE settings.**
- **For PE events, the cyclical process (define MoM, measure sensitivity, collect data, evaluate data, report) needs to also capture critical C4ISR data and effects.**

RECOMMENDATIONS

- **Develop broadly-accepted TOR for PE: definitions, objectives, goals, distinguishing relationships from OOTW to MTW**
- **Develop CSOP for PE**
- **Develop MoMs and data collection checklists for PE**
- **Expand JULLS formats and databases to include C4ISR data**
- **Study the impact of deploying C4ISR in peacetime. Assess the utility of C4ISR deployment on its own. Assess how early C4ISR deployment facilitates early combat power by follow-on forces.**

Summary:

KEY ISSUES

- The nature of the world, and the threat, has changed since the end of the Cold War. The distribution of risk of warfare is quite different, with more uncertainty about the probabilities of specific threats. There is a need to collect data and develop the distribution of events on the current and future spectra of conflict.

RECOMMENDATIONS

- Recognizing PE as an important mission area, with attendant principles and distinguishing relationships, will assist in identifying the peculiar tasks of PE, and garnering funding for their successful undertaking.
- Common Standard Operating Procedures must account for the many differences (historical, cultural, financial, educational, etc.) that exist in the many countries that we engage during PE operations. "One size fits all" is not the answer. We need to KNOW our PE "targets" much better, and tailor each engagement to that particular country. Specific C4ISR exchanges are good candidate elements for tailored PE.
- Expansion of the Joint Uniform Lessons Learned (JULLS) database to include C4ISR data and information will help long term analysis of C4ISR issues.

Analyzing C4ISR for 2010

Synthesis Group

Synthesis Group
Synthesis Team

- **Major Theater Warfare (MTW)**
  - **Denny Baer, Logicon**
  - **Jerry Kotchka, Boeing**
- **Smaller Scale Contingencies (SSC)**
  - **Dave Alberts, OASD(C3I)**
- **Operations Other Than War (OOTW)**
  - **Russ Richards, MITRE**
- **Peacetime Engagement**
  - **Clay Thomas, USAF**
  - **Bill Kemple, NPS**
- **Infrastructure Assurance (IA)**
  - **Stuart Starr, MITRE**
- **Information Architectures**
  - **Larry Wiener, DoN**
- **Analytical Techniques and Tools**
  - **Denis Clements, GRCI**
  - **Jay Kistler, USN**
  - **Steve Myer, USA**
- **Floaters**
  - **Bob Eberth, USNR**
  - **Pat Peterson, USN**

Synthesis Team:

The Synthesis Team was created to develop a holistic view of the deliberations of all of the Working Groups participating in the Workshop. Consistent with that goal, a team was selected that included representation from OSD, each of the Services, industry, FFRDCs and academia. Selected members of the Synthesis Team actively participated in each of the Working Groups (see the Viewgraph for the specific assignments). The Synthesis Team convened periodically during the course of the Workshop to discuss and compare the evolving findings and recommendations of each Working Group. Drawing on those deliberations, the Synthesis Team developed some broad observations about the nature of the problem and formulated a set of cross-cutting findings and recommendations. These products are presented and discussed below.

Synthesis Group
Broad Observations

- **There is broad variability in the "maturity" of the mission areas; i.e., most mature to least mature:**
  - **-- MTW**
  - **-- SSC**
  - **-- OOTW**
  - **-- Peacetime Engagement**
  - **-- Infrastructure Assurance**
- **Selected mission areas (e.g., OOTW) subsume sub-missions that are qualitatively different (e.g., HA/DR, PK/PE)**

Broad Observations:

As a consequence of monitoring the deliberations of the individual Mission Oriented Working Groups it became clear that there was broad variability in the maturity of the individual mission areas (e.g., level of domain knowledge; available tools and data; experience in analyzing the C4ISR systems and processes associated with those missions). Based on the perceptions of the Synthesis Team, it was concluded that one could rank order the missions on a qualitative "maturity scale" as follows: Major Theater War, Smaller Scale Contingency, Operations Other Than War, Peacetime Engagement and Infrastructure Assurance.

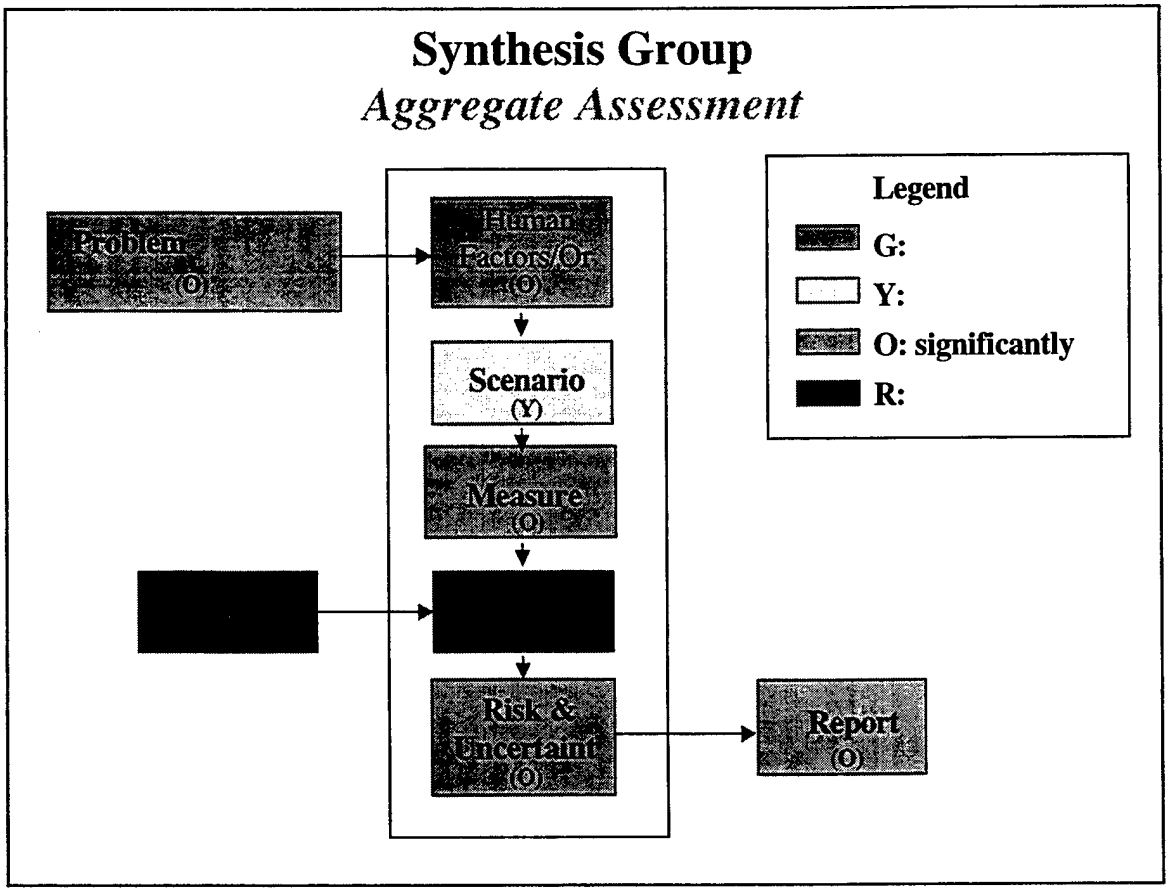
The Synthesis Team observed further that many of these mission areas subsume qualitatively different sub-missions. For example, Operations Other Than War subsumes Humanitarian Assistance, Disaster Relief, Peace Keeping and Peace Enforcement. These sub-missions are so different in their nature and maturity that it can be misleading to make overarching statements about the overall mission area.

Synthesis Group
Major Issues

Mission Area	*Major Issues*
MTW	Few accepted data sources; Modeling Red C4ISR; Existing data does not map to DPG scenarios
SSC	MoMs need sufficient pre-definition
OOTW	Data; Softness of MoMs (public opinion); OOTWs are not all the same
Peacetime Engagement	Definition
Infrastructure Assurance	Data (much of it is Blue data); Scope of problem/ability to decompose meaningfully; Higher level MoMs; Dealing with the interactive nature of the problem
Info Arch	How does one score an architecture and communicate the results appropriately?
Tools & Tech	Cognitive modeling; Broad array of missions; Size of the trade space; Representation of Red data

Major Issues:

As the Synthesis Team monitored the deliberations of the individual Working Groups it identified several major issues that were raised by those Working Groups. The associated viewgraph briefly summarizes those major issues. Note that although there are considerable differences in those issues, several cross-cutting issues are apparent. These cross-cutting issues involve difficulties associated with data and measures of merit (MoMs). These specific cross-cutting issues will be highlighted in the findings and recommendations that follow.



Aggregate Assessment:

In his plenary presentation, Stuart Starr introduced a template that was developed in the forthcoming NATO Code of Best Practice (COBP) for Assessing Command and Control. [Note: for information purposes, a brief summary of the highlights of the NATO COBP is included as Annex A]. That template identified the life cycle of the C2 assessment process, emphasizing the key steps that are followed by leading practitioners of C2 assessment. Each of the Working Groups used this template to assess the current state of the health of C2 assessment for their mission area. The associated viewgraph provides an aggregate assessment, qualitatively integrated across the results of the individual Working Group assessments. It can be seen that two of the critical steps (i.e., data, tools) were assessed as being poor ("Red"), five of the steps (i.e., problem structuring, treatment of human factors/organization, measures of merit, treatment of risk and uncertainty, report documentation and availability) were assessed as being significantly deficient ("orange"), and one step (i.e., scenario generation) was assessed as being fair ("yellow"). It is notable that, on aggregate, none of the steps were assessed as being good ('green").

These observations suggest that there is widespread concern about the community's ability to adhere to the processes in a strawman COBP. These results led the Synthesis Group to highlight findings and recommendations in five areas: COBP, three key

elements of the candidate COBP and the overall relationship between the producer and consumer of C2 analyses. These findings and recommendations are summarized below.

Synthesis Group
Code of Best Practices (COBP): Findings

- **Findings**
  - **A community-endorsed COBP is needed to provide a sound foundation for**
    - **structuring,**
    - **addressing the C2 assessment problem, in all its dimensions**

Code of Best Practices (COBP) – Findings:

The Synthesis Working Group concluded that the NATO COBP represented an interesting initial step towards developing a sound foundation for C2 assessment. However, that product was restricted in its scope to assessing C2 in the context of conventional warfare. As this Workshop revealed, the problem of analyzing C4ISR for 2010 will involve a host of additional mission areas, which pose unique problems for the C2 assessment community. Thus, an expanded, community-endorsed COBP is needed to support the C2 assessment problem, in all its dimensions.

Synthesis Group
Code of Best Practices (COBP): Recommendations

Recommendations:

- **An assessment should be made of the NATO COBP to see if it meets the needs of the US C2 assessment community (Action: MORS)**
- **If the assessment endorses the COBP, it should be**
  - **broadly disseminated to the C2 assessment community (Action: MORS)**
  - **employed in defense universities to educate young analysts (Action: NPS, AFIT)**
- **Efforts should be supported to extend the NATO COBP to address New World Disorder issues (Action: SAS Panel-015)**

Code of Best Practices (COBP) – Recommendations:

Although the preliminary review of the NATO COBP was promising, it is recommended that a more thorough, in-depth assessment of the product should be undertaken to see if it meets (at least some of) the needs of the US C2 analysis community. MORS is in the best position of any US organization to organize and execute such an assessment.

If such an assessment is undertaken and it endorses the NATO COBP as a preliminary product, the following steps should be pursued. First, the product should be disseminated broadly to the C2 assessment community, along with any caveats that emerged through the assessment process. MORS has an efficient distribution network for making such information broadly available. Second, consideration should be given to employing the product in defense universities, such as the Naval Postgraduate School (NPS) and the Air Force Institute of Technology (AFIT), to educate young analysts.

In view of the limited scope of the NATO COBP, efforts should be supported to extend the product to address New World Disorder issues. NATO is forming Studies, Analysis and Simulation (SAS) Panel-015, to explore the feasibility of extending the initial COBP to deal with issues associated with OOTW and Information Operations. Those efforts should be supported by MORS (e.g., by providing: representatives to the deliberations; appropriate briefings/case studies to the participants; a peer-review of the panel's product) to ensure that the resulting efforts are of greatest utility to the US C2 assessment community.

Synthesis Group
Measures of Merit (MoMs): Findings

- **Findings**
  - **MORS' concept of a hierarchy of MoMs appears valid**
  - **However,**
    - **the hierarchy must be extended to deal with the needs of New World Disorder missions**
    - **MoMs are lacking to support the effective assessment, comparison of architectural options**

Measures of Merit -- Findings:

Over the last thirteen years, MORS has conducted several workshops on the issue of developing Measures of Merit (MoMs) for command and control assessments [Ref. 1, 2]. Those workshops proposed the concept of a hierarchy of MoMs that would range from measures of system performance through measures of mission effectiveness. [Note: see Figure 3 in the appended paper].The various mission-oriented working groups at this workshop appeared to support this conceptual approach to the problem. However, it was concluded that the hierarchy must be extended to deal with the needs of New World Disorder missions.

The Architecture Working Group also observed that it lacked MoMs to support the effective assessment and comparison of architectural options. In particular, it called for MoMs that would relate system architectural characteristics to operational outcomes.

Synthesis Group

Measures of Merit (MoMs): Recommendations

- **Recommendations**
  - **Formulate upper levels of the MoM hierarchy to reflect effectiveness of C4ISR with respect to**
    - **political-institutional stability (e.g., OOTW, SSC)**
    - **public confidence in institutions (e.g., IA)**
  - **Explore options to develop MoMs that can be used to assess and compare architectural options (e.g., relate system architectural characteristics to operational outcomes)**
    (Action: OSD host key decision makers; MORS facilitate)

Measures of Merit -- Recommendations:

To respond to the needs of New World Disorder missions, efforts are needed to formulate the upper levels of the MoM hierarchy. For example, in the mission areas of Smaller Scale Contingencies and Operations Other Than War, measures are needed to characterize political-institutional-social stability (e.g., are the bodies of government functioning effectively; are educational institutions operative; are children playing on soccer fields). Similarly, in the area of Infrastructure Assurance, there is a need for MoMs that reflect public confidence in key infrastructures (e.g., confidence in the finance and banking sector as measured by the value of the Dow Jones Industrial Average and the value of the dollar versus the Euro). These needs suggest the need for MORS to convene a workshop on expanded C4ISR MoMs for New World Disorder missions.

To satisfy the needs of the Architectural community, steps should be taken to explore options to develop MoMs that can be used to assess and compare architectural options. One possible course of action would call for OSD to convene an Integrated Process Team (IPT) of stakeholder organizations to address this issue. MORS could provide the facilitators to conduct such an event.

Synthesis Group
Data: Findings

- **Findings**
  - **Data issues were highlighted by each Working Group**
  - **Specific concerns varied by Group**
    - **Dealing with data appropriate to future operations (e.g., MTW)**
    - **Acquiring needed Blue system data (e.g., IA)**
    - **Characterizing Red C4ISR, infrastructure (e.g., MTW, IA)**
    - **Gaining access to data in a timely fashion (All)**
    - **Collecting and making better use of data emerging from experimentation (e.g., MTW, SSC, OOTW)**
    - **"...there is no V&C worthy of the name" (Eberth)**

Data – Findings:

A decade ago, at a MORS Workshop on Simulation Technology 1997 (SIMTECH 97), Dr. Walt LaBerge observed that "without data we are nothing" [Ref. 3]. That thought clearly prevailed in this workshop and data issues were highlighted by each Working Group. The specific concerns varied by Working Group and included the following challenges: acquiring the data appropriate to some currently ill-defined future military operation; acquiring the Blue system data needed to perform vulnerability assessments of critical infrastructures; characterizing Red's C4ISR systems and critical infrastructures; gaining access to needed data in a timely fashion; collecting and making better use of data emerging from Service and Joint Advanced War fighting Experiments. One of the members of the Synthesis Working Group also observed that there is "... no validation and certification worthy of the name."

Synthesis Group
Data: Recommendations

- **Establish an institutional mechanism for acquiring, VV&Cing, transforming, storing and making accessible key data**
- **Draw on the capabilities and resources of key organizations (e.g., DSC, PA&E (e.g., JDS), DMSO (e.g., MSOSA), J6 (e.g., JDIICS, NETWARS)) (Action: OASD(C3I))**

Data – Recommendations:

The depth and breadth of these data concerns are such that a new institutional mechanism is needed to deal with the totality of the problem. This mechanism should deal with the full life cycle of the data problem, to include data acquisition, verification, validation and certification (VV&C), transformation (into a form that is useful to the C2 assessment community), storage and access. Currently, there are a number of organizations that are involved with significant facets of the problem. These include OSD's C4ISR Decision Support Center (DSC), PA&E's Joint Data System (JDS), Defense Modeling and Simulation Office (DMSO) Modeling and Simulation Operational Support Activities (MSOSA) and J6's Joint Defense Information Infrastructure Control System (JDIICS) and NETWARS activities. OASD(C3I) should take the lead in forging these fragmented efforts into a complete, mutually reinforcing solution to the total problem.

Synthesis Group
Tools and Their Application: Findings

- **Findings**
  - **There is no single tool (or class of tools) that can satisfy C2 assessment needs adequately**

Tools and Their Application – Findings:

Many of the speakers at the workshop focused their remarks on modeling and simulation and its potential role in C2 assessment. It is clear, however, that no single class of tool (and certainly no single tool within a class) can satisfy C2 assessment needs adequately.

Synthesis Group

Tools and Their Application: Recommendations

- **Recommendations**
  - **Encourage the use of a broad mix of tools that are well suited to the critical issues of interest; e.g.,**
    - **analyses, based on basic principles**
    - **structured expert elicitation tools**
    - **creative applications of "New Sciences" to deal with Complex Adaptive Systems**
    - **multi-functional tools (e.g., support to analysis and rehearsal)**
  - **Assiduously pursue efforts to perform responsible levels of VV&A (Action: MORS)**
  - **Apply these tools iteratively (e.g., generalization of the Model-Test-Model paradigm)**

Tools and Their Application – Recommendations:

There is a broad spectrum of tools that a C2 analyst can chose from, that vary with respect to the time to create and apply them, the cost to create and apply them and their credibility. [Note: see Figure 4 in the appended paper]. It is important that C2 assessors be aware that this broad mix of tools exists (beyond the "usual suspects" of M&S) and be conversant about their strengths and weaknesses. In particular, where appropriate, C2 assessments should take better advantage of analyses, based on basic operations research and physical principles; structured expert elicitation tools (e.g., group ware); applications of the "New Sciences" to deal with Complex Adaptive Systems; and multifunctional tools (e.g., tools that can support analyses and mission rehearsal). In all instances, assessors should assiduously pursue efforts to perform responsible levels of verification, validation and accreditation (VV&A) for the tools selected. MORS should lead the way in determining what is a "responsible level of VV&A." [Note: it is anticipated that SIMVAL 99 will shed light on this issue].

Because of the strengths and weaknesses of these tools, it is important to select and orchestrate a complementary set of tools. In the past, this concept has been limited to the Model-Test-Model paradigm. However, it would be appropriate to generalize that concept to incorporate a broader set of tool types. For example, it might be desirable to consider a "expert elicitation-real world experience-test-model" paradigm, that expands the set of tools that are orchestrated.

Synthesis Group

Provider-Consumer Relations: Findings

- **Findings**
  - **Providers are failing to make their analyses transparent, understandable**
  - **Consumers are frequently not "educated customers"**

Provider-Consumer Relations – Findings:

Many of the Working Groups observed that relations between the providers and consumers of C2 assessment are strained. They noted that many providers, by relying on complex, opaque M&S are failing to make their analyses transparent and understandable (e.g., "Why did I come to that conclusion? My model told me!"). Similarly, consumers are frequently not "educated customers." For example, they fail to articulate issues in a way that is amenable to responsible C2 assessment, or they fail to give the provider adequate resources to either create the needed tools or to perform the assessment.

Synthesis Group

Provider-Consumer Relations: Recommendations

- **Recommendations**
  - **There should be a "contract" between providers and consumers, recognizing the mutual responsibilities of both sides**
  - **A COBP should be developed (perhaps in the form of a check list) to help educate consumers about the attributes of sound C4ISR assessment**
    (Action: MORS)

Provider-Consumer Relations – Recommendations:

This issue was recognized and addressed at the MORS Mini-Symposium on "Quick Reaction Analysis Requirements and Methodologies (QRAM)" [Ref. 4]. The Synthesis Working Group at that workshop recognized that there should be a "contract" between providers and consumers, recognizing the mutual responsibilities of both sides. It is recommended that the draft "contract" be updated and refined to reflect the lessons learned from this workshop.

As a further step, a COBP should be developed (perhaps in the form of a checklist) to help educate consumers about the attributes of sound C4ISR assessment. This "check list" could be patterned after the COBP that the AIAA Information & C2 System Technical Committee is developing for OSD on C2 experimentation.

Synthesis Group

Summary

- **Good News**
  - **We are beginning to understand**
    - **the importance of C4ISR**
    - **the practices that should be followed to perform credible C4ISR analyses**
    - **... and what we don't understand!**
- **Bad News**
  - **Currently, we generally do not do a satisfying job in performing C4ISR analyses**
- **Worse News**
  - **With the arrival of the New World Disorder, the C4ISR assessment problem is getting substantially more difficult**
- **Better News**
  - **If the recommendations of the workshop are implemented, it will provide the foundation for the C4ISR community to work collaboratively to attack the most critical of our shortfalls**

Summary:

The Synthesis Group discerned news on C2 assessment that ran the gamut from good to bad to worse to better.

The good news is that we are beginning to understand a great deal more about the C2 assessment problem. We are starting to recognize the importance of C4ISR in the context of the many missions that DoD must perform; the practices that should be followed to perform credible C4ISR analyses; ... and what we don't yet understand!

The bad news is that currently, we generally do not do a satisfying job in performing C4ISR analyses. Although there are counter-examples to this statement, it is recognized that most studies of conventional conflict fail to live up to the COBP generated by NATO's SAS Panel-002.

The worse news is that the C2 assessment problem is getting substantially more difficult. We are confronted with a host of New World Disorder missions and issues for which we lack the key elements of effective C2 analyses (particularly relevant data and tools). In addition, these issues are in a constant state of flux, making it difficult to get traction on the problem. One of the most dramatic examples of this challenge is the Infrastructure Assurance problem, where the infrastructures and the threats to them are changing dramatically.

Although these are daunting challenges, there is some better news that is implicit in this workshop itself. If the recommendations of the workshop are implemented successfully, it will have provided the foundation for the C4ISR community to work collaboratively to attack the most critical of our shortfalls.

C4ISR Mini-Symposium/Workshop
Acronyms

AFIT	Air Force Institute of Technology
AFSA/SAAB	Airforce Studies and Analysis Activity
AIAA	American Institute of Astronautics and Aeronautics
ARES	Regional Exploratory Simulation
ASD	Assistant Secretary of Defense
ASD(C3I)	Assistant Secretary of Defense for Command, Control, Communications and Intelligence
AWACS	Airborne Warning and Control Systems
BMDO	Ballistic Missile Defense Office
C2	Command and Control
C3	Command, Control and Communications
C3I	Command, Control, Communication and Intelligence
C3IEW	Command, Control, Communications, Intelligence and Electronic Warfare
C4I	Command, Control, Communications, Computers and Intelligence.
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CAS	Complex Adaptive Systems
CCIR	Commander's Critical Information Requirement
CCRP	C2 Research Program
CENTCOM	[US] Central Command
CIP	Critical Infrastructure Protection
CMA	C4ISR Mission Assessment
COA	Course of Action.
COBP	Code of Best Practices
COMINT	Communications Intelligence
CONOPS	Concept of Operations
COP	Common Operational Picture
COTS	Commercial-Off-The-Shelf
CSOP	Current State of Practice
DCI	1. Director of Central Intelligence; 2. Dual Channel Interchange; 3. Document Change Instruction
DD	Variation of DoD
DDR&E	Director Defense Research and Evaluation

DepSECDEF/VCJCS	Deputy Secretary of Defense/Vice Chairman, Joint Chiefs of Staff
DM	Decision Maker
DMSO	Defense Modeling and Simulation Office
DoD	Department of Defense
DoN	Department of the Navy
DPG	Defense Planning Guidance
DR/HA	Disaster Relief/Humanitarian Assistance
DSC	Decision Support Center
DSTF	Decision Support Task Force
ELINT	Electronic Intelligence
FER	Force Exchange Ratio
FFRDC	Federally Funded Research and Development Center
GO	General Officer
GPS	1. Global Positioning System; 2. Global Protection System
GRCI	General Research Corporation Inc
HA/DR	Higher Authority/Deployment Review
HEAT	Headquarters Effectiveness Assessment Tool
HUMINT	Human Intelligence
IA	Infrastructure Assurance
ICBM	Inter-Continental Ballistic Missile
IFFN	Identify Friend or Foe Network
IMINT	Imagery Intelligence
IO	Information Operations
IPB	Intelligence Preparation of the Battlefield
IPS	Integrated Program Summary
IPT	Integrated Process Team
IR	Infrared
ISR	Intelligence, Surveillance and Reconnaissance
J-2	Joint Staff Section 2 (Intelligence)
J-6	Joint Staff Section 6 (Command, Control, Communications and Computers)
J-8	Joint Staff Section 8
JAMIP	Joint Analytic Model Improvement Program
JBC	Joint C4ISR Battle Center
JCAPS	Joint C4SI Architecture Planning/Analysis System
JDIICS	Joint Defense Information Infrastructure Control System
JDS	Joint Data System
JROC	Joint Requirements Oversight Council

JTF	Joint Task Force
JWARS	Joint Warfighting System
JWCA	Joint Warfighting Capability Assessment
M&S	Modeling and Simulation
MAGTG	Marine Air Ground Task Force
MASINT	Measurement and Signals Intelligence
MCES	Modular C2 Evaluation Structure
MOA	Mission Oriented Approach
MOEs	Measure of Effectiveness
MOFEs	Measure of Force Effectiveness
MoME	Measure of Mission Effectiveness
MoMs	Measures of Merit
MoPE	Measure of Policy Effectiveness
MoPs	Measure of Performance
MORS	Military Operations Research Society
MOPE	Measure of Performance Effectiveness
MSOSA	Modeling and Simulation Operational Support Activities
MTI	Moving Target Indicator
MTW	Major Theater War
NAI's	Named Area's of Interest
NATO	North Atlantic Treaty Organization
NEO	Non-Combatant Evacuation Operation
NGO	Non Governmental Organization
NPS	Naval Postgraduate School
NSS	Naval Simulation System
OOTW	Operations Other Than War
OP	Optical Processing
OPNAV	Office of the Chief of Naval Operations
OASD	Office of the Assistant Secretary of Defense
OSD	Office of the Secretary of Defense
PA&E	Program Analysis and Evaluation
PACOM	[United States] Pacific Command
PDD	Presidential Decision Directive
PE	Peacetime Engagement
PED	Processing, Exploitation and Dissemination
PK/PE	Peace Keeping/Peace Enforcement
PK/PE/PB	Peace Keeping/Peace Enforcement/Peace Building
POM	Program Objective Memorandum

PPBS	Planning, Programming, Budgeting System
PPE	President's Program Element
PSYOPS	Psychological Operations
QDR	Quadrennial Defense Review
QRAM	Quick Response Analysis Methodologies
Recce	Reconnaissance
RMA	Revolutionary in Military Affairs
ROE	Rules of Engagement
ROI	Return on Investment
SAC	Strategic Air Command
SAS	Panel Studies, Analysis and Simulations
SBA	Simulation Based Acquisition
SCUDs	Surface to Surface Missile System
SECDEF	Secretary of Defense
SIGINT	Signals Intelligence
SIMTECH	Simulation Technology
SIMVAL	Simulation Validation
SPAM	Sensor Platform Allocation Model
SSC	Smaller Scale Contingencies
TASC	The Analytical Sciences Group
TMD	Theater Missile Defense
TOR	Terms of Reference
TRAC-WSMR	Training and Doctrine Command Analysis Center/White Sands Missile Range
UHF	Ultra High Frequency
UN	United Nations
US	United States
USA	United States Army
USACOM	United States Atlantic Command
USFK	United States Forces Korea
USN	United States Navy
V&C	Validation and Certification
V&V	Verification and Validation
VIC	Vector In Commander
VV&A	Verification, Validation and Accreditation
VV&C	Verification, Validation and Certification
WMD	Weapons of Mass Destruction

TERMS OF REFERENCE
Analyzing C4ISR for 2010 Workshop

Background

The Revolution in Military Affairs has already begun to transform our command and control procedures and architectures, as we struggle to adapt our institutions to the realities of the Information Age. Recent seminal defense planning documents, e.g., Joint Vision 2010, Quadrennial Defense Review, and the National Defense Panel report, have highlighted the critical role of information technology-based C4ISR for future US forces. A broader spectrum of threats and operations, a smaller more capable force, and an information technology-based society require greatly improved C4ISR capabilities. In our resource-constrained environment, however, decision makers face tough choices in determining the allocation of investment between C4ISR and the other contributors to force effectiveness (e.g., platforms and weapons, modernization, sustainment, logistics). The analytical community must be able to provide cogent analyses to support these decisions. What has been missing heretofore is the ability to assess effectively the relative contribution of C4ISR to force effectiveness vis-a-vis other factors. Past analyses — with their component metrics, methodologies, and tools — have not been adequate for this new emphasis. The analytic community must now posture itself to address the analysis of C4ISR for 2010 and beyond.

This special meeting, comprising analysts and C4ISR subject matter experts, will concentrate on the improvement of analysis of C4ISR for a US force and doctrine heavily reliant on information technologies. To achieve this end, participants will enumerate potential decision maker issues and define the appropriate analytic metrics, methodologies, and tools for C4ISR analysis. These issues will be addressed by working groups covering the spectrum of military operations, as well as information infrastructures and leading-edge analytical techniques.

Goals and Objectives

Goals. This workshop will afford the military OR community an opportunity to achieve the following goals: (1) share information on the current state of C4ISR analysis; (2) determine the appropriate metrics and methodologies for analysis of C4ISR for 2010; and (3) define key areas of improvement for the application of analysis in support of decision making on C4ISR investments and warfighting utility. The results will provide insights into how to advance the ability of the OR community to conduct analysis of C4ISR in support of Joint Vision 2010 and beyond.

Objectives. The objectives are to:

- Enumerate the relevant issues pertaining to the analysis of C4ISR in 2010
- Identify metrics that are sensitive to the effects of C4ISR on force-level effectiveness
- Assess methodologies to analyze and quantify the effectiveness of C4ISR
- Evaluate appropriate tools to measure the benefit of C4ISR
- Discuss the requirements for and employment of advanced tools, methods, and research.

Approach

In order to achieve these goals and objectives, the subject of C4ISR analysis will be examined in a number of different contexts. A working group will examine C4ISR analysis within each contextual framework. Working groups will be asked to address some baseline issues (as a starting point) and provide specific results. The working group contexts, baseline issues, and desired results are detailed below.

Working Groups. The workshop attendees will be organized into working groups (18- 20 members each) to examine the analysis of C4ISR within these specific focus areas:

- Major Theater War
- Smaller Scale Contingencies
- Operations Other Than War
- Infrastructure Assurance
- Peacetime Engagement
- Information Architectures
- Analytical Techniques and Tools
- Synthesis

A. Major Theater War. Co-chairs: Dr. Mark Youngren and Chuck Taylor. This working group will focus on C4ISR within the context of large-scale, joint and combined operations against a technologically sophisticated adversary. These highly complex operations will require fusion of all-source intelligence, seamless integration of sensors, platforms, and command organizations, and intense logistic support to allow a greater number of operational tasks to be accomplished faster. An important consideration for this group is ascertaining our ability to determine the relative contributions of C4ISR and platforms/weapons to force effectiveness.

B. Smaller Scale Contingencies. Chair: Dick Hayes. This working group will focus on C4ISR in the context of smaller scale operations, including "show of force", crisis response, raids, opposed (or potentially opposed) noncombatant evacuations, sanction enforcement, special operations, and counterterrorism. These operations may require covert Intelligence-Surveillance-Reconnaissance (ISR) and communications, flexible contingency planning, command and control responsive to national as well as tactical concerns, and highly portable, reconfigurable, and secure joint support systems. They may also involve interagency or coalition issues.

C. Operations Other Than War. Co-chairs: Dr. Cy Staniec, John Furman and Terry Prosser. This working group will focus on C4ISR within the context of OOTW. In order to bolster regional stability, US forces are increasingly likely to be involved in disaster relief, humanitarian assistance, peacekeeping and peace enforcement, and similar non-traditional military missions. In these settings, coordination with non-DoD entities (e.g., State Department), non-governmental organizations (e.g., International Red Cross), and host nation governments will entail unique C4ISR requirements.

D. Infrastructure Assurance. Co-chairs: Thomas Bozek and Frank Ruggeri. This working group will focus on defense of key elements of national infrastructure. DoD is dependent on a complex framework of networks and systems to provide the continual flow of essential goods and services, including information, electrical power, finance and banking, transportation, fuel distribution, health care, and emergency services. The military infrastructure is characterized by increasingly interdependent mix of defense and commercial services; reliance on commercial

services; interdependency among services driven by changing business practices and applied information technology; and vulnerabilities to failures and disruptions from asymmetric attacks, malicious intrusion, inadvertent error, and natural disasters.

E. Peacetime Engagement. Chair: Bruce Powers. This working group will focus on the peacetime presence of US forces throughout the globe as a means to safeguard our vital national interests, promote regional stability, deter potential adversaries, and build cooperative relations with the world's most influential countries. In maintaining a substantial overseas presence, we will maintain the capability to conduct the full range of military operations through a combination of permanently stationed forces, rotationally deployed forces, temporarily deployed forces, and infrastructure.

F. Information Architectures. Chair: Patsy McGrady. This working group will focus on the implications of information architecture (system, technical, and operational) for the analysis of C4ISR. Included in this discussion will be information management (process) and infrastructure. Critical questions include how can analysis contribute to developing information management architectures and doctrines that will facilitate getting the right information to the right place at the right time and can analysis be flexible enough to evaluate alternative processes.

G. Analytical Techniques and Tools. Co-chairs: Dr. Alfred Brandstein and Dr. Roy Rice. This working group will focus on the leading edge of analysis, specifically the latest developments in modeling (e.g., genetic algorithms) and their applicability to the analysis of C4ISR. Define the appropriate use of various methodological constructs (process, case-based, network-oriented, etc.) to conduct C4ISR analysis. Address the adequacy of supporting algorithms, simulations, experiments, and exercises.

H. Synthesis Working Group. Chair: Dr. Stuart Starr. This working group will take a broader view, determine any commonality of issues and concerns across the spectrum of working groups, and provide an integrating perspective. Two specific issues of interest for this group will be the utility of the Joint Warfare System (JWARS) and the important of information dominance.

Tasking. Working groups will be directed to address the following questions and concerns in the following priority order:

> Characterize C4ISR within the working group focus area. Structure and decompose the elements of C4ISR. Describe the scenario space, key factors, and concerns that potentially affect the analysis and representation of C4ISR. Comment on the adequacy of current mission area CONOPS to support assessment of the C4ISR contribution in that area.
>
> Define the relative worth of C4ISR. What are the relative contributions of C4ISR (information), firepower (weapons and platforms), and force employment strategies (e.g., Dominant Maneuver)? How can analysts make meaningful tradeoff analyses? What are the breakpoints in C4ISR capability and spread?
>
> Develop and recommend Measures of Merit. Characterize and organize — for primary (warfare) and secondary (C4ISR) functions — the applicable measures, metrics, and variables including Measures of Performance (MOPs), Measures of Effectiveness (MOEs), Measures of Force Effectiveness (MOFEs), etc. Assess how well these metrics can establish the value of C4ISR relative to other contributors to force effectiveness.

Evaluate how current-or new-metrics can be used to calculate Return on Investment (ROI) for C4ISR.

Identify and describe tools. Identify and describe models, simulations, decision support systems, and other C4ISR-applicable software tools in terms of capability, status, effectiveness, and ability to contribute to the development of operational and technical architectures. Identify needs for new software tools to support advanced C4ISR analysis.

Analyze, synthesize, and infer. Identify common issues and concerns across each of the four topic areas and draw generalized conclusions and make relevant recommendations.

Sequence of Events. The morning of the first day will be devoted to a plenary session for speakers. The speakers will provide differing perspectives on the problem of C4ISR analysis. The keynote speaker will be asked to provide the perspective of the decision maker as the ultimate customer of analytical products. The second speaker(s) will provide an operational perspective, specifically the view of various CINCs. The last speaker will provide a technical perspective. At the end of these sessions, the Chair will provide a charge to the working groups to ensure all participants share a common vision of the products required. The afternoon will be devoted to working group sessions under the supervision of the working group chairs to begin discussions on the designated evaluation issue. At the end of this day, there will be a social event (mixer). The second day will be devoted to parallel working group sessions to further develop their discussions. There will be a luncheon speaker on this day. The morning of the third day will consist of final working sessions to finalize their presentations and written products, followed by a plenary sessions for working group presentations.

Attendees

Attendance will be controlled via invitation. Attendees will include invited experts from OSD, all Services, the Joint Staff, Federally Funded Research and Development Centers, operational commanders, and DoD contractors. Workshop chairs will control membership of their sessions in conjunction with the Organizing Committee. Attendance will be limited to 150 people.

Products

There will be four specific products generated as a result of this workshop:

- A scripted briefing for the MORS Sponsors addressing the workshop objectives, findings, conclusions, and recommendations.
- A proceedings containing summaries of all sessions and copies of appropriate briefing slides and presentations.
- A general session presentation for the 67th MORSS.
- A *PHALANX* article

Proponents

Proponents for the workshop are:

Army Deputy Under Secretary of the Army (Operations Research) (DUSA(OR))
Navy Director of Program Resource Appraisal, Chief of Naval Operations (N81)
Director for Command and Control, DCS, Air and Space Operations, HQUSAF

Planning and Organizing Committee

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Technical Chair:	Dr. Russ Richards The MITRE Co 1820 Dolley Madison Blvd McLean, VA 22102 (703) 883-6787
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Organizing Committee:	Army - TBA Air Force - Clayton J. Thomas, FS, AFSAA Marines – Dr. Alfred Brandstein OSD - Dr. Jackie Henningsen, FS Joint Staff - Peter Byrne NRO - TBA DISA - TBA

At large:

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Administration

Name: Analysis of C4ISR 2010
Dates: 27-29 October 1998
Location: Center for Strategic Leadership, Carlisle Barracks, PA
Fee: Federal Government Employees $175; All others $350
Attendance: Limited to 150
Classification: SECRET

Agenda

Tuesday - 27 October

0700	Registration and Continental Breakfast		Bliss Hall
0800	MORS President's Welcome	Denny Baer	
0810	Welcome by Commandant Army War College	MG Robert Scales, USA	
0820	Overview of Workshop	RADM Nutwell, USN	
	Introduction of Keynote Speaker		
0840	Keynote: "The Decision Maker's Perspective"	Mr. Art Money, ASD(C3I)	
0930	"The Operators Perspective"	TBA	
1030	Break		
	"C3I – The Past, Present and Future"	Dr. Stuart Starr, MITRE	
1145	Transportation from Bliss Hall to Collins Hall		
1200	Catered Lunch		Collins Hall
1300	Working Group Sessions		
1430	Break		
1700	Mixer		Letort View Comm. Center

Wednesday - 28 October

0715	Continental Breakfast		Collins Hall
0800	Working Group Discussions		
1145	Transportation from Collins Hall to Letort View Community Center		
1200	Buffet Lunch With Guest Speaker:		
	"Federated analysis of C4ISR in Warfare"	Mr.Charles Taylor, OASD(C3I)/DSC	Letort View Comm. Center
1315	Transportation from Letort View Community Center to Collins Hall		
1330	Working Group Sessions		Collins Hall
1430	Break		
1700	Adjourn		

Thursday - 29 October

0715	Continental Breakfast		Collins Hall
0800	Working Group: Prepare Briefings to Summarize Deliberations		
1000	Plenary Session: "Blackhawk Down"	Mark Bowden	Letort View Comm. Center
1200	Catered Lunch		
1300	Plenary Session: Working Group Reports	WG Chairs	Bliss Hall
1315	Major Theater War		
1330	Smaller Scale Contingencies		
1345	Operations Other Than War		
1400	Peacetime Engagement		
1415	Infrastructure Assurance		
1430	Break		
1445	Information Architectures		
1500	Analytical Techniques and Tools		
1515	Synthesis		
1530	Closing Remarks	RADM Nutwell	
1600	Adjourn Workshop		

Milestone Plan

Date	"D"	Task	Responsibility
30 Jan	-270	Initiate draft TOR procedure	Initiator
31 Mar	-210	Select tentative dates	Initiator, MORS
30 Apr	-180	Provide "For Comment" draft of TOR to Sponsors, VP(MO) and other interested organizations and individuals for review	MORS office
30 May	-150	Revise TOR	Initiator, MORS office
9 Jun	-140	Circulate initial draft TOR to MORS Office and committee for comments	Chair
		Solicit candidate for working group chairs	
29 Jun	-120	Circulate final draft TOR to MORS Office and proponents for concurrence and to other Sponsors and organizations for information	MORS office
29 Jul	-90	Approve TOR, program chair, budget and fees	Executive Council
		Select working group chairs	Chair
3 Aug	-85	Mail ACP, if appropriate	MORS office
8 Aug	-80	Select organization to be invited and prepare letter inviting nominations	Chair
13 Aug	-75	Mail invitations to nominating organizations	Chair
28 Aug	-60	Select read-ahead material	Chair
		Select nominations or requests for applications	Nominating orgs.
7 Sep	-50	Select invitees	Committee
12 Sep	-45	Assign nominees to working groups	Committee
		Mail invitations and working group assignments	MORS office
		Provide read-ahead materials and releases to MORS office	Committee
17 Sep	-40	Mail read-ahead materials	MORS office
2 Oct	-25	Pre-registration, security clearances due to MORS office	Invitees
27- 29 Oct		***Conduct workshop***	***Chair/Committee***
26 Nov	30	Brief Sponsors	Chair
26 Dec	60	Submit After-Action Report	Chair
25 Jan	90	Complete written products	Committee
24 Feb	120	Approve written products	Publications committee
26 Mar	150	Review approved products	Proponents
25 Apr	180	Distribute approved products	MORS office

1. 28 September 1998

Military Operations Research Society

Analyzing C4ISR for 2010 Workshop

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